

ENT COOPERATION TRE.

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION
(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
 United States Patent and Trademark
 Office
 Box PCT
 Washington, D.C.20231
 ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 28 January 2000 (28.01.00)	Assistant Commissioner for Patents United States Patent and Trademark Office Box PCT Washington, D.C.20231 ÉTATS-UNIS D'AMÉRIQUE
International application No. PCT/SG99/00012	Applicant's or agent's file reference GM/AY/R33-60
International filing date (day/month/year) 12 February 1999 (12.02.99)	Priority date (day/month/year) 12 May 1998 (12.05.98)
Applicant DING, Shou-Wei	

1. The designated Office is hereby notified of its election made:

in the demand filed with the International Preliminary Examining Authority on:

22 November 1999 (22.11.99)

in a notice effecting later election filed with the International Bureau on:

2. The election was

was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer F. Gateau
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PCT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis.1 and
Administrative Instructions, Section 422)

Date of mailing (day/month/year) 25 July 2000 (25.07.00)	To: ELLA CHEONG & G. MIRANDAH P.O. Box 0931 Raffles City Singapore 911732 SINGAPOUR
Applicant's or agent's file reference GM/AY/R33-60	IMPORTANT NOTIFICATION
International application No. PCT/SG99/00012	International filing date (day/month/year) 12 February 1999 (12.02.99)

1. The following indications appeared on record concerning:				
<input checked="" type="checkbox"/> the applicant <input type="checkbox"/> the inventor <input type="checkbox"/> the agent <input type="checkbox"/> the common representative				
Name and Address INSTITUTE OF MOLECULAR A 1 Research Link Singapore 117604 Singapore		State of Nationality SG	State of Residence SG	
		Telephone No.		
		Facsimile No.		
		Telex No.		
2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:				
<input type="checkbox"/> the person <input type="checkbox"/> the name <input checked="" type="checkbox"/> the address <input type="checkbox"/> the nationality <input type="checkbox"/> the residence				
Name and Address INSTITUTE OF MOLECULAR AGROBIOLOGY The National University of Singapore 1 Research Link Singapore 117604 Singapore		State of Nationality SG	State of Residence SG	
		Telephone No.		
		Facsimile No.		
		Telex No.		
3. Further observations, if necessary:				
4. A copy of this notification has been sent to:				
<input checked="" type="checkbox"/> the receiving Office <input type="checkbox"/> the International Searching Authority <input checked="" type="checkbox"/> the International Preliminary Examining Authority		<input type="checkbox"/> the designated Offices concerned <input checked="" type="checkbox"/> the elected Offices concerned <input type="checkbox"/> other:		

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer Ingrid Aulich Telephone No.: (41-22) 338.83.38
---	---

TENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference GM/AY/R33-60	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/SG 99/00012	International filing date (day/month/year) 12/02/1999	(Earliest) Priority Date (day/month/year) 12/05/1998
Applicant INSTITUTE OF MOLECULAR AGROBIOLOGY et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:

- contained in the international application in written form.
- filed together with the international application in computer readable form.
- furnished subsequently to this Authority in written form.
- furnished subsequently to this Authority in computer readable form.
- the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. Certain claims were found unsearchable (See Box I).

3. Unity of invention is lacking (see Box II).

4. With regard to the title,

the text is approved as submitted by the applicant.

the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

the text is approved as submitted by the applicant.

the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. _____

as suggested by the applicant.

because the applicant failed to suggest a figure.

because this figure better characterizes the invention.

None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SG 99/00012

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12N15/82 C07K14/08 C12N15/62 A01H5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DING, S-W., ET AL.: "a novel naturally occurring hybrid gene encoded by a plant RNA virus facilitates long distance virus movement" THE EMBO JOURNAL, vol. 14, no. 23, 1995, pages 5762-5772, XP002089661 cited in the application abstract; Fig.1; page 5763, right column; page 5765 + 5766 + 5770 --- -/-	1-37

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

27 July 1999

Date of mailing of the international search report

10/08/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Holtof, S

INTERNATIONAL SEARCH REPORT

National Application No
PCT/SG 99/00012

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DING, S-W., ET AL.: "an interspecies hybrid RNA virus is significantly more virulent than either parental virus" PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE USA, vol. 93, July 1996 (1996-07), pages 7470-7474, XP002089662 cited in the application the whole document ---	1-37
A	DING, S-W., ET AL.: "efficient infection from cDNA clones of cucumber mosaic cucumovirus RNAs in a new plasmid vector" JOURNAL OF GENERAL VIROLOGY, vol. 76, 1995, pages 459-464, XP002089663 abstract ---	1-37
A	DING, S-W., ET AL.: "new overlapping gene encoded by the cucumber mosaic virus genome" VIROLOGY, vol. 198, 1994, pages 593-601, XP002089664 cited in the application abstract; page 593, 595, 596; Fig. 1,2; page 597-600 ---	1-37
A	WO 93 25068 A (CORNELL RES FOUNDATION INC) 23 December 1993 (1993-12-23) page 2; examples 11-14 ---	1-37
A	WO 96 21032 A (ASGROW SEED CO ;TRICOLI DAVID M (US); CARNEY KIM J (US); RUSSELL P) 11 July 1996 (1996-07-11) üpage 2,3,12 ---	1-37
A	WO 91 15585 A (RIJKSLANDBOUWHOGESCHOOL) 17 October 1991 (1991-10-17) abstract; pages 2,6; claims ---	1-37
T	LI, H-W., ET AL.: "strong host resistance targeted against a viral suppressor of the plant gene silencing defence mechanism" THE EMBO JOURNAL, vol. 18, no. 10, May 1999 (1999-05), pages 2683-2691, XP002110358 the whole document -----	24-37

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

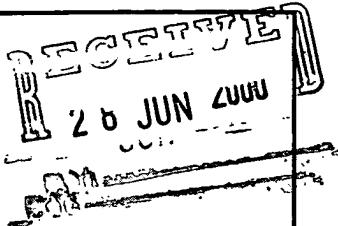
PCT/SG 99/00012

Patent document cited in search report	Publication date	Patent family member(s)			Publication date
WO 9325068	A 23-12-1993	EP 0673423 A	27-09-1995		
		JP 7507457 T	24-08-1995		
		US 5633449 A	27-05-1997		
		US 5596132 A	21-01-1997		
WO 9621032	A 11-07-1996	AU 2690295 A	24-07-1996		
		EP 0819176 A	21-01-1998		
		TR 960640 A	21-07-1996		
WO 9115585	A 17-10-1991	NL 9000773 A	01-11-1991		
		AT 174931 T	15-01-1999		
		AU 642252 B	14-10-1993		
		AU 7684591 A	30-10-1991		
		CA 2056439 A	03-10-1991		
		DE 69130660 D	04-02-1999		
		DE 69130660 T	17-06-1999		
		EP 0474857 A	18-03-1992		
		EP 0874055 A	28-10-1998		
		ES 2128318 T	16-05-1999		
		JP 5505110 T	05-08-1993		
		PT 97230 A, B	31-12-1991		
		US 5866776 A	02-02-1999		

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

Ella Cheong & G. Mirandah
PO Box 0931
Raffles City
SINGAPORE 911732

**PCT**

NOTIFICATION OF TRANSMITTAL OF
INTERNATIONAL PRELIMINARY EXAMINATION
REPORT

(PCT Rule 71.1)

Date of mailing
day/month/year

20 JUN 2000

IMPORTANT NOTIFICATION

Applicant's or agent's file reference
GM/MC/R33-60/ja

International application No.
PCT/SG99/00012

International filing date
12 February 1999

Priority date
12 May 1998

Applicant
INSTITUTE OF MOLECULAR AGROBIOLOGY

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.
2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.
3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translations to those Offices.

REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide

Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer T. SUMMERS Telephone No. (02) 6283 2291
---	--

ENT COOPERATION TREATY
PCT
INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference GM/MC/R33-60/ja	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).	
International application No. PCT/SG99/00012	International filing date (<i>day/month/year</i>) 12 February 1999	Priority Date (<i>day/month/year</i>) 12 May 1998	
International Patent Classification (IPC) or national classification and IPC Int. Cl. 7 C12N 15/82, C07K 14/08, C12N 15/62, A01H 5/00			
Applicant INSTITUTE OF MOLECULAR AGROBIOLOGY			

1.	This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.		
2.	This REPORT consists of a total of 4 sheets, including this cover sheet. <input type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT). These annexes consist of a total of sheet(s).		
3.	This report contains indications relating to the following items:		
I	<input checked="" type="checkbox"/> Basis of the report		
II	<input type="checkbox"/> Priority		
III	<input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability		
IV	<input type="checkbox"/> Lack of unity of invention		
V	<input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement		
VI	<input type="checkbox"/> Certain documents cited		
VII	<input type="checkbox"/> Certain defects in the international application		
VIII	<input checked="" type="checkbox"/> Certain observations on the international application		

Date of submission of the demand 22 November 1999	Date of completion of the report 3 April 2000
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer T. SUMMERS Telephone No. (02) 6283 2291

I. Basis of the report

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Inventive step (IS)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Industrial applicability (IA)	Claims 1-37	YES
	Claims	NO

2. Citations and explanations (Rule 70.7)

The most relevant documents cited in the international search report are:

D1 Ding S-W *Proc Natl. Acad. Sci. USA* (1996), 93, 7470-7474

D2 Ding S-W *J. Gen. Virol.* (1995), 76, 459-464

D1 and D2 disclose the expression vector defined in claim 21. D2 discloses a plasmid vector comprising the 35S transcription promoter from cauliflower mosaic virus operably linked to the full length cDNA clones of cucumber mosaic cucumovirus strain Q. The transcription promoter is a plant-active promoter (cf. page 13 line 33 to page 14 line 2 of the application). The cDNA codes for the cucumber mosaic cucumovirus 2b gene (Cmv2b) (abstract and disclosed plasmid pQCD2). D1 discloses the same plasmid pQCD2 (see Fig. 1). D1 additionally discloses plasmid vector pQCDqt in which the Cmv2b coding sequence is replaced by the tomato aspermy cucumovirus 2b (Tav2b) coding sequence (page 7471 first paragraph under "Results").

D1 also discloses transgenic plants prepared by transfecting tobacco protoplasts with viral particles of cucumber mosaic cucumovirus (CMV) and a hybrid cucumber mosaic cucumovirus in which the Cmv2b coding sequence is replaced by the Tav2b coding sequence (CMV-qt) (second complete paragraph of text on page 7471, the paragraph bridging the columns on page 7472 and Fig. 2). The virus contains a promoter capable of affecting expression of the 2b gene in the host plant. Consequently claims 1-9 and 18-23 are anticipated by D1.

D1 and D2 neither disclose or suggest that the cucumovirus 2b gene may be useful in rendering a plant resistant to disease nor disclose or suggest that the Avr gene contains a cell death domain. Consequently claims 10-17 and 24-37 are novel and possess an inventive step.

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

1. Claims 1, 4, 10, 13, 21 and 22 are unclear due to the use of the term "active fragment thereof". The specification describes genes possessing both pathogen resistance activity and cell death activity. It is unclear which activity the claims refer to.
2. As a result these claims lack descriptive support because the description provides support for only the active fragments having pathogen resistance activity.
3. The claims lack descriptive support. The claims define aspects involving the cucumovirus 2b gene. However, the description provides support for only where the cucumovirus 2b gene is the tomato aspermy cucumovirus 2b gene (Tav2b). Although the specification also describes the related cucumovirus 2b gene, cucumber mosaic cucumovirus 2b gene (Cmv2b), this gene is described as possessing *no* pathogen resistance activity (see for example page 20 lines 11-13 and page 27 lines 21-24 and page 30 lines 1-2). Similarly the description provides support for only where the Avr gene (claims 24, 25, 27, 28, 30, 31 and 33) is the Tav2b gene.

PATENT COOPERATION TREATY
PCT
INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference GM/MC/R33-60/ja	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).	
International application No. PCT/SG99/00012	International filing date (day/month/year) 12 February 1999	Priority Date (day/month/year) 12 May 1998	
International Patent Classification (IPC) or national classification and IPC Int. Cl. 7 C12N 15/82, C07K 14/08, C12N 15/62, A01H 5/00			
Applicant INSTITUTE OF MOLECULAR AGROBIOLOGY			

<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 4 sheets, including this cover sheet.</p> <p><input type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of sheet(s).</p>																	
<p>3. This report contains indications relating to the following items:</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%;">I</td> <td style="width: 90%;"><input checked="" type="checkbox"/> Basis of the report</td> </tr> <tr> <td>II</td> <td><input type="checkbox"/> Priority</td> </tr> <tr> <td>III</td> <td><input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td> </tr> <tr> <td>IV</td> <td><input type="checkbox"/> Lack of unity of invention</td> </tr> <tr> <td>V</td> <td><input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td> </tr> <tr> <td>VI</td> <td><input type="checkbox"/> Certain documents cited</td> </tr> <tr> <td>VII</td> <td><input type="checkbox"/> Certain defects in the international application</td> </tr> <tr> <td>VIII</td> <td><input checked="" type="checkbox"/> Certain observations on the international application</td> </tr> </table>		I	<input checked="" type="checkbox"/> Basis of the report	II	<input type="checkbox"/> Priority	III	<input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability	IV	<input type="checkbox"/> Lack of unity of invention	V	<input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement	VI	<input type="checkbox"/> Certain documents cited	VII	<input type="checkbox"/> Certain defects in the international application	VIII	<input checked="" type="checkbox"/> Certain observations on the international application
I	<input checked="" type="checkbox"/> Basis of the report																
II	<input type="checkbox"/> Priority																
III	<input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability																
IV	<input type="checkbox"/> Lack of unity of invention																
V	<input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement																
VI	<input type="checkbox"/> Certain documents cited																
VII	<input type="checkbox"/> Certain defects in the international application																
VIII	<input checked="" type="checkbox"/> Certain observations on the international application																

Date of submission of the demand 22 November 1999	Date of completion of the report 3 April 2000
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer T. SUMMERS Telephone No. (02) 6283 2291

I. Basis of the report

1. With regard to the elements of the international application:*

the international application as originally filed.

the description, pages , as originally filed,
 pages , filed with the demand,
 pages , received on with the letter of

the claims, pages , as originally filed,
 pages , as amended (together with any statement) under Article 19,
 pages , filed with the demand,
 pages , received on with the letter of

the drawings, pages , as originally filed,
 pages , filed with the demand,
 pages , received on with the letter of

the sequence listing part of the description:
 pages , as originally filed
 pages , filed with the demand
 pages , received on with the letter of

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language which is:

the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

the language of publication of the international application (under Rule 48.3(b)).

the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, was on the basis of the sequence listing:

contained in the international application in written form.

filed together with the international application in computer readable form.

furnished subsequently to this Authority in written form.

furnished subsequently to this Authority in computer readable form.

The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. The amendments have resulted in the cancellation of:

the description, pages

the claims, Nos.

the drawings, sheets/fig.

5. This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Inventive step (IS)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Industrial applicability (IA)	Claims 1-37	YES
	Claims	NO

2. Citations and explanations (Rule 70.7)

The most relevant documents cited in the international search report are:

D1 Ding S-W *Proc Natl. Acad. Sci. USA* (1996), 93, 7470-7474

D2 Ding S-W *J. Gen. Virol.* (1995), 76, 459-464

D1 and D2 disclose the expression vector defined in claim 21. D2 discloses a plasmid vector comprising the 35S transcription promoter from cauliflower mosaic virus operably linked to the full length cDNA clones of cucumber mosaic cucumovirus strain Q. The transcription promoter is a plant-active promoter (cf. page 13 line 33 to page 14 line 2 of the application). The cDNA codes for the cucumber mosaic cucumovirus 2b gene (Cmv2b) (abstract and disclosed plasmid pQCD2). D1 discloses the same plasmid pQCD2 (see Fig. 1). D1 additionally discloses plasmid vector pQCDqt in which the Cmv2b coding sequence is replaced by the tomato aspermy cucumovirus 2b (Tav2b) coding sequence (page 7471 first paragraph under "Results").

D1 also discloses transgenic plants prepared by transfecting tobacco protoplasts with viral particles of cucumber mosaic cucumovirus (CMV) and a hybrid cucumber mosaic cucumovirus in which the Cmv2b coding sequence is replaced by the Tav2b coding sequence (CMV-qt) (second complete paragraph of text on page 7471, the paragraph bridging the columns on page 7472 and Fig. 2). The virus contains a promoter capable of affecting expression of the 2b gene in the host plant. Consequently claims 1-9 and 18-23 are anticipated by D1.

D1 and D2 neither disclose or suggest that the cucumovirus 2b gene may be useful in rendering a plant resistant to disease nor disclose or suggest that the Avr gene contains a cell death domain. Consequently claims 10-17 and 24-37 are novel and possess an inventive step.

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

1. Claims 1, 4, 10, 13, 21 and 22 are unclear due to the use of the term "active fragment thereof". The specification describes genes possessing both pathogen resistance activity and cell death activity. It is unclear which activity the claims refer to.
2. As a result these claims lack descriptive support because the description provides support for only the active fragments having pathogen resistance activity.
3. The claims lack descriptive support. The claims define aspects involving the cucumovirus 2b gene. However, the description provides support for only where the cucumovirus 2b gene is the tomato aspermy cucumovirus 2b gene (Tav2b). Although the specification also describes the related cucumovirus 2b gene, cucumber mosaic cucumovirus 2b gene (Cmv2b), this gene is described as possessing *no* pathogen resistance activity (see for example page 20 lines 11-13 and page 27 lines 21-24 and page 30 lines 1-2). Similarly the description provides support for only where the Avr gene (claims 24, 25, 27, 28, 30, 31 and 33) is the Tav2b gene.

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To: ELLA CHEONG & G. MIRANDAH PO BOX 0931 RAFFLES CITY SINGAPORE 911732	PCT 28 JAN 2000 WRITTEN OPINION (PCT Rule 66)
---	---

Applicant's or agent's file reference GM/MC/R33-60		Date of mailing (day/month/year) 19 JAN 2000
International application No. PCT/SG 99/00012	International filing date (day/month/year) 12 February 1999	Priority Date (day/month/year) 12 May 1998
International Patent Classification (IPC) or both national classification and IPC Int. Cl. 7 C12N 15/82, C07K 14/08, C12N 15/62, A01H 5/00		
Applicant INSTITUTE OF MOLECULAR AGROBIOLOGY		

1. This written opinion is the **first** drawn by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

I	<input checked="" type="checkbox"/> Basis of the opinion
II	<input type="checkbox"/> Priority
III	<input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	<input type="checkbox"/> Lack of unity of invention
V	<input checked="" type="checkbox"/> Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	<input type="checkbox"/> Certain documents cited
VII	<input type="checkbox"/> Certain defects in the international application
VIII	<input checked="" type="checkbox"/> Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also For an additional opportunity to submit amendments, see Rule 66.4. For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4bis. For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: **12 September 2000**

Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer T. SUMMERS Telephone No. (02) 6283 2291
--	---

VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

1. Claims 1, 4, 10, 13, 21 and 22 are unclear due to the use of the term "active fragment thereof". The specification describes genes possessing both pathogen resistance activity and cell death activity. It is unclear which activity the claims refer to.
2. As a result these claims lack descriptive support because the description provides support for only the active fragments having pathogen resistance activity.
3. The claims lack descriptive support. The claims define aspects involving the cucumovirus 2b gene. However, the description provides support for only where the cucumovirus 2b gene is the tomato aspermy cucumovirus 2b gene (Tav2b). Although the specification also describes the related cucumovirus 2b gene, cucumber mosaic cucumovirus 2b gene (Cmv2b), this gene is described as possessing *no* pathogen resistance activity (see for example page 20 lines 11-13 and page 27 lines 21-24 and page 30 lines 1-2). Similarly the description provides support for only where the Avr gene (claims 24, 25, 27, 28, 30, 31 and 33) is the Tav2b gene.

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Inventive step (IS)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Industrial applicability (IA)	Claims 1-37	YES
	Claims	NO

2. Citations and explanations

The most relevant documents cited in the international search report are:

D1 Ding S-W *Proc Natl. Acad. Sci. USA* (1996), 93, 7470-7474

D2 Ding S-W *J. Gen. Virol.* (1995), 76, 459-464

D1 and D2 disclose the expression vector defined in claim 21. D2 discloses a plasmid vector comprising the 35S transcription promoter from cauliflower mosaic virus operably linked to the full length cDNA clones of cucumber mosaic cucumovirus strain Q. The transcription promoter is a plant-active promoter (cf. page 13 line 33 to page 14 line 2 of the application). The cDNA codes for the cucumber mosaic cucumovirus 2b gene (Cmv2b) (abstract and disclosed plasmid pQCD2). D1 discloses the same plasmid pQCD2 (see Fig. 1). D1 additionally discloses plasmid vector pQCDqt in which the Cmv2b coding sequence is replaced by the tomato aspermy cucumovirus 2b (Tav2b) coding sequence (page 7471 first paragraph under "Results").

D1 also discloses transgenic plants prepared by transfecting tobacco protoplasts with viral particles of cucumber mosaic cucumovirus (CMV) and a hybrid cucumber mosaic cucumovirus in which the Cmv2b coding sequence is replaced by the Tav2b coding sequence (CMV-qt) (second complete paragraph of text on page 7471, the paragraph bridging the columns on page 7472 and Fig. 2). The virus contains a promoter capable of affecting expression of the 2b gene in the host plant. Consequently claims 1-9 and 18-23 are anticipated by D1.

D1 and D2 neither disclose or suggest that the cucumovirus 2b gene may be useful in rendering a plant resistant to disease nor disclose or suggest that the Avr gene contains a cell death domain. Consequently claims 10-17 and 24-37 are novel and possess an inventive step.

PATENT COOPERATION TREATY
PCT
INTERNATIONAL PRELIMINARY EXAMINATION REPORT

REC'D 20 JUN 2000

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference GM/MC/R33-60/ja	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).	
International application No. PCT/SG99/00012	International filing date (day/month/year) 12 February 1999	Priority Date (day/month/year) 12 May 1998	
International Patent Classification (IPC) or national classification and IPC Int. Cl. ⁷ C12N 15/82, C07K 14/08, C12N 15/62, A01H 5/00			
Applicant INSTITUTE OF MOLECULAR AGROBIOLOGY			

<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 4 sheets, including this cover sheet.</p> <p><input type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of sheet(s).</p>																	
<p>3. This report contains indications relating to the following items:</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%; text-align: left; padding-right: 10px;">I</td> <td style="width: 90%;"><input checked="" type="checkbox"/> Basis of the report</td> </tr> <tr> <td style="text-align: left; padding-right: 10px;">II</td> <td><input type="checkbox"/> Priority</td> </tr> <tr> <td style="text-align: left; padding-right: 10px;">III</td> <td><input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td> </tr> <tr> <td style="text-align: left; padding-right: 10px;">IV</td> <td><input type="checkbox"/> Lack of unity of invention</td> </tr> <tr> <td style="text-align: left; padding-right: 10px;">V</td> <td><input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td> </tr> <tr> <td style="text-align: left; padding-right: 10px;">VI</td> <td><input type="checkbox"/> Certain documents cited</td> </tr> <tr> <td style="text-align: left; padding-right: 10px;">VII</td> <td><input type="checkbox"/> Certain defects in the international application</td> </tr> <tr> <td style="text-align: left; padding-right: 10px;">VIII</td> <td><input checked="" type="checkbox"/> Certain observations on the international application</td> </tr> </table>		I	<input checked="" type="checkbox"/> Basis of the report	II	<input type="checkbox"/> Priority	III	<input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability	IV	<input type="checkbox"/> Lack of unity of invention	V	<input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement	VI	<input type="checkbox"/> Certain documents cited	VII	<input type="checkbox"/> Certain defects in the international application	VIII	<input checked="" type="checkbox"/> Certain observations on the international application
I	<input checked="" type="checkbox"/> Basis of the report																
II	<input type="checkbox"/> Priority																
III	<input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability																
IV	<input type="checkbox"/> Lack of unity of invention																
V	<input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement																
VI	<input type="checkbox"/> Certain documents cited																
VII	<input type="checkbox"/> Certain defects in the international application																
VIII	<input checked="" type="checkbox"/> Certain observations on the international application																

Date of submission of the demand 22 November 1999	Date of completion of the report 3 April 2000
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer T. SUMMERS Telephone No. (02) 6283 2291

I. Basis of the report

1. With regard to the elements of the international application:*

 the international application as originally filed. the description, pages , as originally filed,
 pages , filed with the demand,
 pages , received on with the letter of the claims, pages , as originally filed,
 pages , as amended (together with any statement) under Article 19,
 pages , filed with the demand, the drawings, pages , received on with the letter of
 pages , as originally filed,
 pages , filed with the demand, the sequence listing part of the description:
 pages , as originally filed
 pages , filed with the demand
 pages , received on with the letter of

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language which is:

 the language of a translation furnished for the purposes of international search (under Rule 23.1(b)). the language of publication of the international application (under Rule 48.3(b)). the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, was on the basis of the sequence listing:

 contained in the international application in written form. filed together with the international application in computer readable form. furnished subsequently to this Authority in written form. furnished subsequently to this Authority in computer readable form. The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished. The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished4. The amendments have resulted in the cancellation of: the description, pages the claims, Nos. the drawings, sheets/fig.5. This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Inventive step (IS)	Claims 10-17, 24-37	YES
	Claims 1-9, 18-23	NO
Industrial applicability (IA)	Claims 1-37	YES
	Claims	NO

2. Citations and explanations (Rule 70.7)

The most relevant documents cited in the international search report are:

D1 Ding S-W *Proc Natl. Acad. Sci. USA* (1996), 93, 7470-7474

D2 Ding S-W *J. Gen. Virol.* (1995), 76, 459-464

D1 and D2 disclose the expression vector defined in claim 21. D2 discloses a plasmid vector comprising the 35S transcription promoter from cauliflower mosaic virus operably linked to the full length cDNA clones of cucumber mosaic cucumovirus strain Q. The transcription promoter is a plant-active promoter (cf. page 13 line 33 to page 14 line 2 of the application). The cDNA codes for the cucumber mosaic cucumovirus 2b gene (Cmv2b) (abstract and disclosed plasmid pQCD2). D1 discloses the same plasmid pQCD2 (see Fig. 1). D1 additionally discloses plasmid vector pQCDqt in which the Cmv2b coding sequence is replaced by the tomato aspermity cucumovirus 2b (Tav2b) coding sequence (page 7471 first paragraph under "Results").

D1 also discloses transgenic plants prepared by transfecting tobacco protoplasts with viral particles of cucumber mosaic cucumovirus (CMV) and a hybrid cucumber mosaic cucumovirus in which the Cmv2b coding sequence is replaced by the Tav2b coding sequence (CMV-qt) (second complete paragraph of text on page 7471, the paragraph bridging the columns on page 7472 and Fig. 2). The virus contains a promoter capable of affecting expression of the 2b gene in the host plant. Consequently claims 1-9 and 18-23 are anticipated by D1.

D1 and D2 neither disclose or suggest that the cucumovirus 2b gene may be useful in rendering a plant resistant to disease nor disclose or suggest that the Avr gene contains a cell death domain. Consequently claims 10-17 and 24-37 are novel and possess an inventive step.

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

1. Claims 1, 4, 10, 13, 21 and 22 are unclear due to the use of the term "active fragment thereof". The specification describes genes possessing both pathogen resistance activity and cell death activity. It is unclear which activity the claims refer to.
2. As a result these claims lack descriptive support because the description provides support for only the active fragments having pathogen resistance activity.
3. The claims lack descriptive support. The claims define aspects involving the cucumovirus 2b gene. However, the description provides support for only where the cucumovirus 2b gene is the tomato aspermy cucumovirus 2b gene (Tav2b). Although the specification also describes the related cucumovirus 2b gene, cucumber mosaic cucumovirus 2b gene (Cmv2b), this gene is described as possessing *no* pathogen resistance activity (see for example page 20 lines 11-13 and page 27 lines 21-24 and page 30 lines 1-2). Similarly the description provides support for only where the Avr gene (claims 24, 25, 27, 28, 30, 31 and 33) is the Tav2b gene.



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : C12N 15/82, C07K 14/08, C12N 15/62, A01H 5/00		A1	(11) International Publication Number: WO 99/58697 (43) International Publication Date: 18 November 1999 (18.11.99)
<p>(21) International Application Number: PCT/SG99/00012</p> <p>(22) International Filing Date: 12 February 1999 (12.02.99)</p> <p>(30) Priority Data: PCT/SG98/00035 12 May 1998 (12.05.98) SG</p> <p>(71) Applicant (<i>for all designated States except US</i>): INSTITUTE OF MOLECULAR AGROBIOLOGY [SG/SG]; 1 Research Link, Singapore 117604 (SG).</p> <p>(72) Inventor; and</p> <p>(75) Inventor/Applicant (<i>for US only</i>): DING, Shou-Wei [CN/SG]; The National University of Singapore, 1 Research Link, Singapore 117604 (SG).</p> <p>(74) Agent: ELLA CHEONG & G. MIRANDAH; P.O. Box 0931, Raffles City, Singapore 911732 (SG).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report.</i></p>	

(54) Title: DISEASE RESISTANT TRANSGENIC PLANTS

(57) Abstract

Transgenic plants transformed with a cucumovirus 2b gene or active fragment thereof, or an Avr gene having an inactive cell death domain exhibit resistance to diseases caused by infectious pathogens, such as viruses. Expression of the genes causes activation of hypersensitive response and expression of pathogenicity-related proteins in plants that are incapable of such a response to certain pathogens. Transformation of a wide variety of plants with expression vectors in which such a gene is operably linked to a plant-active promoter renders the plant resistant to pathogenic infection.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		

DISEASE RESISTANT TRANSGENIC PLANTS

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to methods and materials for conferring disease resistance to plants. More particularly, the invention relates to transgenic plants containing a heterologous nucleic acid which confers disease resistance, particularly against infectious pathogens, such as viruses. The invention 10 further relates to methods and materials for preparation of such transgenic plants.

15 Infectious diseases of cultivated plants cause substantial reductions in food, forage and fiber throughout the world. Control of these diseases has been based primarily on cultural practices that include removal of infected debris, eradication of weed hosts (herbicide applications), prevention of vector transmission (pesticide applications), indexing for pathogen-free starting material (seed or vegetative 20 propagules) and breeding for disease resistance. Large scale methods for curing plants once they have become infected with viruses do not exist. Thus, the control of diseases is dependent upon methods to prevent or delay the establishment of infection.

Of the above disease control measures, breeding for resistance is generally one of the most economical and practical methods, as it requires no additional labor or expense to the grower. Moreover, controlling 5 diseases with resistance does not require applications of herbicides or pesticides to eliminate weed hosts and insect vectors. Thus, host resistance is one of the most environmentally safe and durable methods for controlling plant diseases. Unfortunately, in many 10 plant-virus systems, resistance is not available and cannot be obtained using traditional plant-breeding strategies. However, recent advances in molecular biology and gene manipulation have proven helpful in integrating new disease resistance factors into 15 plant-virus systems where none existed before.

Background Art

The development of transgenic plants has proven to be a valuable strategy for protecting plants from viral diseases. For example, Stubbs, G. et al., United 20 States patent 5,723,750 describe transgenic plants expressing genes encoding wild-type and modified coat proteins of different virus groups. These transgenic plants have been shown to have varying levels of resistance to infection by the corresponding virus. 25 Unfortunately, the expression of heterologous genes encoding coat proteins does not confer broad resistance to viral infections and has no effect on pathogenesis caused by other infectious agents.

Gene-for-gene disease resistance is an important 30 plant defense mechanism against pathogens. It is induced only when the host plant carrying a resistance (R) gene is challenged by a pathogen carrying a matching avirulence (Avr) gene (Keen, 1990). (A bibliography is provided at the end of the written 35 description.) The specific interaction between a

matching pair of R-Avr genes usually induces the hypersensitive response ("HR") and results in the local containment of the invading pathogen at sites of attempted ingress. During the HR, the recognition of a pathogen induces a rapid cell death process that results in the formation of a zone of dead cells (necrosis) around the site of infection. This HR lesion is believed to inhibit further spread of the pathogen and to generate a signal that activates host defense mechanisms and, in many cases, induces long-lasting systemic resistance to a broad spectrum of pathogens (Ross, 1961; Ryals et al., 1996; Sticher et al., 1997). Induction of such systemic resistance is termed systemic acquired resistance ("SAR") and is accompanied by an oxidative burst, an increase in the rate of synthesis of several pathogenesis-related ("PR") proteins, alterations in cell-wall structure, and the accumulation of salicylic acid ("SA") (Malamy et al., 1990; Metraux et al., 1990; Ward et al., 1991; Hammond-Kosack and Jones, 1996; Lamb and Dixon, 1997; Yang et al., 1997).

Methods for inducing the HR in infected plants have been described. For example, Lam, E. et al., U.S. patent 5,629,470, have described a process for providing higher plants with enhanced resistance to pathogenic attack by one or more plant pathogens by transforming cells of the plants with the bacterio-opsin (bO) gene.

More than a dozen R genes specific for bacteria, viruses, fungi or nematodes have been cloned from a variety of plant species and it is striking to note that these R genes often encode structurally similar proteins, suggesting a high degree of mechanistic conservation among the pathways that plants use to

trigger defense responses (Baker et al., 1997; Hammond-Kosack and Jones, 1997).

The Avr genes of pathogens by definition encode or produce signal molecules that can initiate HR in the corresponding resistant plants. For example, Avr4 and Avr9 from the extracellular growing fungal pathogen *Cladosporium fulvum* encode pre-proproteins that are processed into small secreted peptides that can elicit R gene-dependent defense responses even in the absence of pathogens (Knogge, 1996). Similarly, the bacterial AvrD locus of *Pseudomonas syringae* pv. glycinea encodes enzymes involved in the synthesis of exported syringolide elicitors which, when injected into the intercellular leaf spaces, can elicit HR in soybean cultivars that carry the Rpg4 gene (Leach and White, 1996). However, for most of the bacterial Avr genes cloned, the Avr protein itself is the elicitor (Leach and White, 1996). These Avr genes generally encode hydrophilic proteins that lack signal sequences and do not induce HR when injected into leaves of plants with the matching R genes. It has recently been demonstrated that recognition of several bacterial Avr gene products by their matching R gene products occurs inside plant cells (Tang et al., 1996; Scofield et al., 1996; Leister et al., 1996; Gopalan et al., 1996; Van den Ackerveken et al., 1996). The import of the Avr proteins into plant cells may be through the type III secretory system encoded by the bacterial Hrp gene cluster required for HR induction and pathogenesis (Pirhonen et al., 1996; Lindgren, 1997).

Plant viruses enter cells through existing wounds and replicate intracellularly. Therefore, it is likely that viral Avr-R recognition also occurs inside plant cells. Most plant viruses have small genomes that encode genes required for replication, movement and

encapsidation. All three major types of viral genes encoding the coat protein (Bendahmane et al., 1995; Berzal-Herranz et al., 1995; Taraporewala and Culver, 1996), RNA replicase (Meshi et al., 1988; Padgett et al., 1997; Kim and Palukaitis, 1997), or movement protein (Meshi et al., 1989; Weber et al., 1993) have been demonstrated to be avirulence determinants. The 126K replicase protein (Padgett et al., 1997) of tobacco mosaic virus (TMV) is the only viral Avr protein for which the cloning of a matching R gene, N, has been reported (Whitham et al., 1994). The N gene product, predicted as a cytoplasmic protein, belongs to the NBS-LRR family of resistance genes (Baker et al., 1997).

It has been reported recently that systemic leaves of nepovirus- and caulimovirus-infected plants exhibit a strong virus resistance similar to post-transcriptional gene silencing ("PTGS"), thus providing evidence for a second type of natural defense mechanism against viruses in plants (Covey et al., 1997; Ratcliff et al., 1997). PTGS was first discovered in transgenic plants and involves the degradation of RNA species that are similar to the transcribed part of a silencer transgene. As a result, only a low level of the transgene RNA exists even if it is transcribed at a high level (Depicker and Van Montagu, 1997). PTGS confers virus resistance in transgenic plants if the silencer transgene is derived from or shares sequence homology with the genome of a plant virus (Lindbo et al., 1993; Guo and Garcia, 1997; Ruiz et al., 1998).

In support of PTGS as a natural plant defense against viruses, two proteins encoded by plant RNA viruses were identified as suppressors of PTGS in transgenic plants (Anandalakshmi et al., 1998; Brigneti et al., 1998; Kasschau and Carrington, 1998). The HC

Pro encoded by potato virus Y blocks the maintenance of PTGS in tissues where silencing has already been established, whereas the 2b protein encoded by cucumber mosaic virus (Cmv2b) prevents the initiation of gene silencing at the growing points of the plants (Brigneti et al., 1998). Both viral proteins have been previously shown to be important for virulence determination and systemic spread (Cronin et al., 1995; Ding et al., 1995). Thus, plant viruses possessing a PTGS suppressor function provide an active and effective strategy to combat innate host resistance mechanisms. This strategy is distinct from the one employed by many plant pathogens to overcome the gene-for-gene disease resistance mechanism which is to accumulate mutations in Avr genes that can escape recognition by corresponding host R genes.

In view of the enormous economic impact of infectious diseases on agricultural production, a need continues to exist for transgenic plants having generalized resistance to pathogenic infections.

SUMMARY OF THE INVENTION

In accordance with the present invention, transgenic plants that have been stably transformed with the 2b gene of cucumovirus or an active fragment thereof have been found to possess systemic resistance to pathogenic infectious agents, such as viruses. The protein encoded by this gene activates strong disease resistance responses in host plants.

A further aspect of the invention relates to seeds and propagating parts of transgenic plants stably transformed with a cucumovirus 2b gene or an active fragment thereof. The invention further provides methods and vectors for introducing the cucumovirus 2b gene into plants.

A further aspect of the invention relates to a plant RNA virus-encoded suppressor of PTGS, which is targeted as an Avr factor by a strong host resistance mechanism resembling the gene-for-gene disease 5 resistance. A molecular dissection of the suppressor indicates a two-domain structure in which one domain is sufficient for resistance activation, while the other was required for triggering hypersensitive cell death. This two-domain structure makes possible a novel class 10 of disease resistance genes comprising disarmed Avr genes, i.e., those without an active cell death induction domain. Disarmed Avr genes can be obtained by such means as domain swapping to link an active resistance domain to an inactive cell death domain, or 15 selective deactivation of an Avr cell death domain. A single such disarmed Avr gene can confer to a transgenic plant broad-spectrum pathogen resistance.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 illustrates the structural features and 20 genome organization of the chimeric viral RNA transcripts from plasmids pTMV-t2b and pPVX-t2b.

Figure 2 is a Northern blot hybridization showing the effect of the 2b gene on expression of the pathogenesis-related protein in leaves of tobacco 25 plants infected with tobacco mosaic virus carrying the 2b gene.

Figure 3 shows the two-domain structure of Tav2b, as revealed by domain mapping. The figure shows plant response to various 2b chimeras. In the figure, HR 30 means observation of necrotic lesions and virus multiplication in the inoculated leaves of *N. tobacum* cv. Samsun nn only, R means observation of virus multiplication in the inoculated leaves only, but with no visible necrotic lesions, S means observation of 35 susceptibility and systemic infection

Figure 4 shows the genomic organization of the TMV-30B vector and the inserted fragments from either TAV or CMV. Boxes represent open reading frames (ORF) encoded by TMV, TAV or CMV. Asterisk (*) denotes the amber stop codon which can be read through to give the 183K protein. The three sgRNA promoters are represented by arrows. Note that this vector is derived from the infectious cDNA clone of TMV-U except for the 3'-terminal sequence, including the coat protein (CP) coding sequence plus its sgRNA promoter (arrow 3), which is from TMV U5 (W.O. Dawson, pers. comm.). The 2b-coding sequences (or their mutants) from TAV (T2b) or CMV (C2b) were cloned at the PmeI site. T Δ 2b1 and T Δ 2b2 are derivatives of T2b with point substitutions that result in partial or complete disruption of the encoded ORF.

Figure 5 shows the accumulation of viral and plant RNAs in tobacco plants. The Samsun plants were inoculated with TMV-30B (TMV), TMV-C2b (C2b), TMV-T Δ 2b2 (T Δ 2b2), TMV-T Δ 2b1, TMV-T2b (T2b or mock-inoculated with buffer alone (M)). At different days post-inoculation (dpi) as indicated, total RNAs were extracted from either the inoculated leaves or systemic leaves and subjected to Northern blot analysis using 32 P-labeled DNA probes specific for TMV genomic RNA (TMV), PR-1a mRNA or the 18 S RNA (as a loading control).

Figure 6 shows the time course of the accumulation of mRNA encoded by PR-1a and PR-5 in the Samsun plants inoculated with TMV-T2b. The time (dpi) when total RNAs were extracted after inoculation is indicated above each lane.

Figure 7 shows accumulation of the six TMV recombinants in the inoculated and systemic leaves of Samsun tobacco plants. A probe for the genomic RNA of

TMV was used for the hybridization. The plant response (as abbreviated in Figure 3) to each of the recombinants is also indicated. For all six recombinants, the 2b coding sequence in the progeny virus was obtained by RT-PCR followed by DNA sequencing and found to be identical to the respective inoculum. M = mock inoculated, CT1 = TMV-CT1, CT2 = TMV-CT2, CT3 = TMV-CT3, TC1 = TMV-TC1, TC2 = TMV-TC2, TC3 = TMV-TC3.

DETAILED DESCRIPTION OF THE INVENTION

Cucumber mosaic virus (CMV) belongs to a virus genus called Cucumovirus which also includes tomato aspermy virus (TAV). Cucumovirus contains a tripartite single-stranded RNA genome that encodes five genes: 1a, 2a, 2b, 3a and coat protein. The identification and functional analysis of the 2b gene have been described in previous publications. (Ding et al., 1994; 1995; 1996). It has been demonstrated that the 2b gene encoded by the cucumoviruses is important for both systemic virus spread and virulence determination. The ribonucleotide sequence of the 2b gene is provided in SEQ ID NO. 1.

It has been discovered that when the 2b gene is expressed separately from the genome of cucumoviruses, it activates strong resistance responses in a variety of plant species upon infection with a pathogenic virus. These responses include induction of pathogenesis-related proteins and formation of necrotic lesions which eliminate the invading pathogens. Thus, in one aspect, the present invention relates to a transgenic plant stably transformed with a cucumovirus 2b gene or active fragment thereof operatively linked to a promoter that is capable of effecting expression of said gene in said plant when said plant is infected with a pathogenic organism. The cucumovirus 2b gene used for producing disease-resistant plants

advantageously is one to which the nucleic acid of SEQ ID NO. 1 will hybridize under stringent conditions.

In a related aspect, the present invention provides methods for rendering a plant resistant to disease caused by an infectious pathogenic agent, which comprises stably transforming the plant with a cucumovirus 2b gene or active fragment thereof operatively linked to a plant-active promoter that is capable of effecting expression of the gene in the plant when said plant is infected with a pathogenic organism. In a further aspect, the invention provides an expression vector comprising a cucumovirus 2b gene or active fragment thereof operably linked to a plant-active promoter.

Mutational analysis has confirmed that the 2b gene is responsible for the resistance response. Point mutations in the gene have been shown to render it non-functional and abolish the ability of the gene to activate the resistance response. In addition, it has been found that the C-terminal 26-amino acid and 45-amino acid sequences of the gene are essential for its disease-resistance function, although the codons encoding the four C-terminal amino acids can be removed without losing activity. Transfer of the codons encoding the C-terminal 26 amino acids and the C-terminal 45 amino acids of the tomato aspermy virus 2b gene to the corresponding regions of the inactive cucumber mosaic virus 2b gene does not yield an active chimeric gene; therefore, the N-terminal portion of the protein also appears to contain one or more domains that are essential for resistance activation. Accordingly, the invention relates to transgenic plants and vectors that contain an active fragment of the 2b gene.

The 2b gene also has been found to be dual functional. Depending on the virus genetic background from which it is expressed, 2b can function as either a virulence or an avirulence determinant. These findings suggest that one may search among susceptible cultivars for R-like genes that can potentially recognize virulent proteins by *in planta* expression from heterologous viral vectors. It is likely that many Avr gene products are virulence factors until a matching R gene evolves in a host cultivar. These results show that the plant gene-for-gene resistance is also effective in targeting as an Avr a virus-encoded suppressor of the plant gene silencing defense mechanism.

While there is a strong association between hypersensitive cell death and gene-for-gene disease resistance, recent studies have provided evidence that cell death is neither required nor sufficient for gene-for-gene resistance. It has been found that TMV-TC2, for example, induced strong virus resistance in the Samsun cultivar without visible hypersensitive cell death (Fig. 3). This result obtained through the molecular dissection of a viral Avr gene supports the view that cell death is not required for resistance.

Domain swapping between an avirulent 2b and its virulent homologue suggests a two-domain structure for an Avr protein. The N-terminal region of 69 amino acids of Tav2b, for example, constitutes the first domain that is essential and sufficient for resistance activation. Thus, both TMV-TC1 and TMV-TC2, encoding a complete resistance domain, induced strong virus resistance in the challenged tobacco plants. Complete (e.g., TMV-CT1, 2 and 3) or partial (e.g., TMV-TC3) replacements or deletion (e.g., TMV-TΔ2b1) of this domain result in the loss of the activity in resistance

activation. The second domain, encompassing amino acids 70-9 of Tav2b, is tentatively referred to as the "cell death" domain because its absence in TMV-TC2 leads to a loss of cell death induction, but without 5 apparent effect on resistance activation. However, although the whole Cmv2b is inactive, it cannot be ruled out that the Cmv2b C-terminal 34 aa fused in TC2 may function as a positive or negative modulator of cell death initiation, leading to a local symptomless 10 phenotype of TMV-TC2. Notably, these two functional domains correspond to the overlapping and non-overlapping regions of the cucumoviral 2b genes, as defined previously according to whether or not it overlaps with the 2a gene (Ding et al., 1995).

15 Distinct from the N-terminal resistance domain (which can act independently), the cell death domain is dependent on the presence of a functional resistance domain. For example, both TMV-CT2 and TMV-CT3 encode a complete cell death domain, but fail to induce necrotic 20 lesions in the inoculated leaves (Fig. 3). Other evidence supporting this observation is that the two amino acid substitutions that rendered Tav2b inactive in triggering resistance and cell death are both located within the resistance domain, but outside of 25 the cell death domain. It is interesting that the resistance domain is functionally independent in contrast to a conditional cell death domain. Thus, cell death signaling, which is usually placed downstream of the Avr-R interaction in the HR network 30 (Hammond-Kosack and Jones, 1996; Lamb and Dixon, 1997), probably involves a subsequent interaction of the pathogen Avr product with another plant protein, possibly via its cell death domain.

35 It will be of practical importance to determine if the concept of the two-domain structure of Tav2b also

applies to Avr genes encoded by any other viral, bacterial and fungal pathogens. Constitutive expression of an Avr gene in a cultivar that contains the matching R gene should generate a constitutive broad-spectrum disease resistance. However, this type of resistance cannot be readily utilized because the specific Avr-R interaction also leads to immediate activation of the hypersensitive cell death (Culver and Dawson, 1991; Gopalan et al., 1996; Leister et al., 1996; Scofield et al., 1996; Tang et al., 1996; Van den Ackerveken et al., 1996; Gilbert et al., 1998). By removing the active cell death domain, swapping it with an inactive cell death domain, or selectively deactivating the cell death domain while maintaining its macrostructural integrity, it would be possible to induce system resistance with cell death. Because the SAR, once induced, is non-specific as to pathogen (be it viral, fungal, bacterial, etc.), it would be possible to confer broad-spectrum resistance by incorporating a single disarmed Avr (preferably disarmed by domain swapping) as a transgene. This is an efficient means of providing a pathogen-resistance plant.

The 2b gene or its active fragment (hereinafter, the "2b gene"), or any Avr useful in this invention, may be introduced into plants using conventional vectors and procedures. Generally, such techniques involve inserting the gene into an expression vector which contains the necessary elements for the transcription and translation of the inserted coding sequences and one or more marker sequences to facilitate selection of transformed cells or plants.

A number of plant-active promoters are known in the art and may be used to effect expression of the nucleic acid sequences disclosed herein. Constitutive

promoters, such as the nos promoter or the 35S promoter of cauliflower mosaic virus, may be used; however, constitutive expression may be harmful to the transgenic plants. Accordingly, inducible promoters, especially pathogen-inducible promoters, such as pathogenesis-related protein promoters are preferred.

Once the gene has been cloned into an expression vector, it may be introduced into a plant cell using conventional transformation procedures. The term "plant cell" is intended to encompass any cell derived from a plant including undifferentiated tissues such as callus and suspension cultures, as well as plant seeds, pollen or plant embryos. Plant tissues suitable for transformation include leaf tissues, root tissues, meristems, protoplasts, hypocotyls, cotyledons, scutellum, shoot apex, root, immature embryo, pollen, and anther.

One technique for transforming plants is by contacting tissue of such plants with an inoculum of a bacterium transformed with a vector comprising the gene in accordance with the present invention. Generally, this procedure involves inoculating the plant tissue with a suspension of bacteria and incubating the tissue for 48 to 72 hours on regeneration medium without antibiotics at 25-28° C.

Bacteria from the genus *Agrobacterium* can be utilized advantageously to transform plant cells. Suitable species of such bacteria include *Agrobacterium tumefaciens* and *Agrobacterium rhizogens*. *Agrobacterium tumefaciens* (e.g., strains LBA4404 or EHA105) is particularly useful due to its well-known ability to transform plants.

Another approach to transforming plant cells with the nucleic acid of this invention involves propelling inert or biologically active particles into plant

cells. This technique is disclosed in U.S. patents 4,945,050, 5,036,006 and 5,100,792 all to Sanford et. al., which are hereby incorporated by reference.

Generally, this procedure involves propelling inert or 5 biologically active particles at the cells under conditions effective to penetrate the outer surface of the cell and to be incorporated within the interior thereof. When inert particles are utilized, the vector can be introduced into the cell by coating the 10 particles with the vector comprising the 2b gene.

Biologically active particles (e.g., dried yeast cells, dried bacterium or a bacteriophage, each containing DNA sought to be introduced) can also be propelled into a plant cell tissue.

15 Another method of transforming plant cells is the electroporation method. This method involves mixing the protoplasts and the desired DNA and forming holes in the cell membranes by electric pulse so as to introduce the DNA into the cells, thereby transforming 20 the cells. This method currently has high reproducibility and various genes have been introduced into monocotyledons, especially rice plants by this method (Toriyama et. al., 1988, Shimamoto et al., 1989 and Rhodes et al., 1988).

25 Similar to the electroporation method is a method in which the desired gene and protoplasts are mixed and the mixture is treated with polyethylene glycol ("PEG"), thereby introducing the gene into the protoplasts. This method is different from the 30 electroporation method in that PEG is used instead of an electric pulse (Zhang W. et. al., 1988, Datta et al., 1990 and Christou et al., 1991).

Other methods include 1) culturing seeds or embryos with nucleic acids (Topfer R. et al., 1989, 35 Ledoux et al., 1974) 2) treatment of pollen tube, (Luo

et al., 1988) 3) liposome method (Caboche, 1990) and 4) the microinjection method (Neuhaus G. et al., 1987).

Known methods for regenerating plants from transformed plant cells may be used in preparing transgenic plants of the present invention. Generally, explants, callus tissues or suspension cultures can be exposed to the appropriate chemical environment (e.g., cytokinin and auxin) so the newly grown cells can differentiate and give rise to embryos which then regenerate into roots and shoots.

The genes of the present invention are useful in enhancing resistance to disease-causing pathogens in both monocotyledonous plants ("monocots") and dicotyledonous plants ("dicots"), such as corn, wheat, rice, millet, oat, barley, sorghum, sunflower, sweet potato, alfalfa, sugar beet, brassica species, tomato, pepper, soybean, tobacco, melon, squash, potato, peanut, pea, cotton or cacao.

The invention is further illustrated by the following examples, which are not intended to be limiting.

EXAMPLES

Example 1

(Vector Construction)

Several efficient *in planta* expression systems based on plant RNA viruses have been developed in recent years. The vectors based on tobacco mosaic virus (TMV) (U.S. patent 5,589,367) and potato virus X (PVX; Chapman et al., 1992) were used in this work for expressing the 2b genes of cucumoviruses. Figure 1 shows the structural features of the chimeric viruses (TMV-t2b and PVX-t2b) that were constructed. The coding

sequence of the 2b gene of TAV (SEQ ID NO. 1, encoding 95 amino acids) was prepared by PCR amplification of the TAV ORF 2b coding sequence (nucleotides 2447-2734 of RNA2) from pQCD2qt (Ding et al., 1996) using the Pfu DNA polymerase (Stratagene). This sequence was inserted into the genome of TMV and PVX upstream of the respective coat protein (CP) gene. The PCR fragment was blunt-end cloned at the *Pme*I site of a TMV vector, known as pTMV-30B, to yield TMV-t2b (Figure 1). The 10 TAV insert in TMV-t2b was excised as an *Age*I - *Xba*I fragment (see Figure 1), and this fragment was end-filled and cloned into *Cla*I-digested and end-filled pPC2S (an expression vector based on potato virus X (Chapman et al., 1992)) to produce PVX-t2b. The 2b 15 gene expression was controlled by independent promoters (arrows labelled as 1 and 3 in Fig. 1) which are recognized only by the respective RNA-dependent RNA polymerase encoded by TMV or PVX.

The 2b-expressing derivatives of TMV or PVX (TMV-t2b and PVX-t2b) were used to infect plants and the functional role of the 2b gene was inferred from differences in the induced plant responses between the wild type and its 2b-expressing derivative.

Example 2(Resistance in *Nicotiana tabacum* Samsun)

TMV-t2b induced a typical hypersensitive response (HR) in Samsun (nn) tobacco plants. Plasmids pTMV-30B, 5 pPC2S and their derivatives were linearized and transcribed *in vitro* as described (Chapman et al., 1992) in the presence of the cap analog (NEB) using the T7 RNA polymerase (Promega). The capped RNA transcripts were inoculated mechanically onto fully 10 developed leaves of *Nicotiana tabacum* cv Samsun (nn). The plants were incubated in the Conviron growth chambers (24°C constant, 75% humidity and 16 hours light/8 hours dark). Local necrotic lesions appeared 15 on the inoculated leaves about 4 days after inoculation and the rest of the plant was symptom-free for as long as observations were made (5 weeks). The failure of TMV-t2b to spread systemically in Samsun (nn) plants was further confirmed by Northern blot analysis which detected no accumulation of viral RNAs in upper 20 uninoculated leaves. Furthermore, transcription of the mRNAs for pathogenesis-related (PR) protein 1 (PR-1), PR-3 and PR-5 was induced in the inoculated leaves. See Figure 2, which is a Northern blot for leaves of plants challenged with TMV-t2b or TMV. Northern blot 25 hybridization was performed using PR-1a cDNA as a probe (obtained by PCR amplification from tobacco plants based on the sequence disclosed by Cornelissen, B.J. et al. (1987)). Total RNAs extracted from plants 5 days (lane 1), 7 days (lane 2), 10 days (lane 3), and 13 30 days (lane 4) showed increasing expression of PR-1. Lanes 5 and 6 were infected with wild-type TMV; however, the tobacco genotype was nn for lane 5 and NN for lane 6.

These results showed that the Samsun (nn) tobacco plants were resistant to TMV-t2b and that challenge inoculation by TMV-t2b induced the expression of both the morphological (local necrotic lesions) and 5 molecular (PR protein induction) markers of HR in the plants.

It is known that *N. tabacum* Samsun (nn) tobacco contains no resistance gene specific to TMV, and this is confirmed in this study that when infected with the 10 vector TMV-30B alone, the tobacco plants developed systemic mosaic symptoms and no induction of the PR genes was observed. Thus, it is concluded that the resistance responses of the tobacco plants to TMV-t2b challenge is due to the *in cis* expression of the TAV 2b 15 gene from the TMV genome.

Example 3

(Demonstration that the 2b Gene is Responsible for Resistance)

Two mutants of TMV-t2b, each containing point 20 mutations to disrupt the open reading frame 2b, were constructed. TMV-tΔ2b1 (SEQ ID NO. 2) is predicted not to translate any of the 2b protein in infected plants. In plants infected with TMV-tΔ2b2 (SEQ ID NO. 3), 25 however, a truncated 2b protein missing the C-terminal 52 amino acid residues is expected to be expressed. Neither TMV-tΔ2b1 nor TMV-tΔ2b2 induced local necrotic lesions in the inoculated leaves and transcription of mRNAs for PR proteins was also not induced. Therefore, it is the TAV 2b protein that functions as the 30 activator of resistance responses. The inserted TAV nucleotide sequence *per se* played no role in the HR elicitation. In addition, it appears that the

C-terminal 52 amino acid sequence of the TAV 2b protein is essential for this activity (see below).

Example 4

(Determination of Resistance Activation Domain)

5 The 2b gene encoded by the Q strain of cucumber mosaic virus (CMV) (SEQ ID NO. 4) was similarly engineered to be expressed from the TMV genome. The derivative, called TMV-q2b, systemically infected Samsun tobacco plants, did not induce necrotic lesions
10 on the inoculated leaves, nor did it induce transcription of mRNAs for PR proteins. This shows that, in contrast to the TAV 2b protein, the CMV 2b protein was inactive in resistance activation.

15 To map the domain important for resistance activation, the TAV 2b protein as encoded by TMV-t2b was progressively replaced from the C-terminus by the structurally equivalent regions of the CMV 2b protein. Infectivity assays showed that replacing the C-terminal four amino acids of the TAV 2b protein retained its HR 20 triggering activity. However, the replacement of the C-terminal 26 or 45 amino acids of the TAV 2b protein abolished its ability to trigger HR. This indicates that the C-terminal 26 amino acids of the TAV 2b protein is essential for resistance activation in 25 tobacco plants, although the codons encoding the four C-terminal amino acids can be removed without losing activity. Transfer of the codons encoding the C-terminal 26 amino acids and the C-terminal 45 amino acids of the tomato aspermy virus 2b gene to the 30 corresponding regions of the inactive cucumber mosaic virus 2b gene does not yield an active chimeric gene; therefore, the N-terminal portion of the protein also

appears to contain one or more domains that are essential for resistance activation.

Example 5

(Resistance in Other Plant Species)

5 Both *Nicotiana benthamiana* and *Physalis floridana* plants are similar to the Samsun tobacco in that they are susceptible to TMV, and the infected plants do not develop HR. Infectivity assays showed that challenge inoculation with TMV-t2b induced typical local necrotic 10 lesions in the inoculated leaves of both *Nicotiana benthamiana* and *Physalis floridana* plants, while the uninfected parts of the plants remained symptom-free. These results suggest that the TAV 2b gene is also capable of activating resistance in these plant species 15 against TMV. The fact that the TAV 2b gene can activate resistance against TMV in three different plant species of two genera suggests that it will function similarly in a wide range of host species.

Example 6

20 (Resistance Against Potato Virus X)

Both Samsun (nn) and Xanthi-nc (NN) tobacco (*N. tabacum*) plants are fully susceptible to potato virus X (PVX) and to the RNA transcripts from the PVX-based vector (pPC2S) (Chapman et al., 1992). However, 25 inoculation with the PVX-t2b transcripts induced HR in leaves of both tobacco varieties. The necrotic lesions induced by PVX-t2b infection were essentially identical to those induced by TMV-t2b on the Samsun (nn) plants. In addition, Northern blot analysis showed that 30 transcription of the PR genes was also induced in plants challenged with PVX-t2b, but not with PVX or the

PVX vector alone. Thus, the TAV 2b gene expression in *cis* from the PVX genome is also capable of triggering the resistance responses in tobacco plants containing no specific resistance gene to PVX.

5 TMV and PVX are distinct plant RNA viruses of different virus genera and the encoded proteins of the two viruses have minimal sequence similarities. Therefore, it is less likely that the resistance activation by the TAV 2b gene requires specific
10 interaction with any of the proteins encoded by the two viral vectors. These results suggests a possibility that the TAV 2b gene will be able to activate resistance mechanisms against a wide range of plant pathogens.

15 Both the wild-type TAV (Ding et al., 1994) and the CMV/TAV chimera CMV-qt (Ding et al., 1996) encode the TAV 2b gene which is expressed at high levels in infected plants (Shi et al., 1997). It has been shown previously that all three plant species used in this
20 work are fully susceptible to TAV and CMV-qt (Ding et al., 1996), suggesting that these plant species do not contain a resistance gene that recognizes the TAV 2b gene. This result indicates that the resistance activation activity of the TAV 2b gene is not
25 constitutive in these plant species and may require an induction event such as infection with certain virulent pathogens (e.g., TMV and PVX). This property distinguishes the TAV 2b gene from the known avirulence genes encoded by plant pathogens.

Example 7

(Methods used for Examples 8-12)

1. Plasmid constructs

DNA manipulations and cloning were carried out
5 using standard procedures (Sambrook et al., 1989)
unless otherwise described. DNA inserts in all
constructs were sequenced in two orientations prior to
use.

Plasmids pTMV-T2b, pTMV-TΔ2b1, pTMV-TΔ2b2 and
10 pTMV-C2b: Plasmid pTMV-30B (Fig. 4, a gift from
Professor W.O. Dawson, University of Florida, USA) is a
plant gene expression vector based on TMV. The coding
sequence of TAV ORF 2b (nucleotides 2447-2734 of RNA2)
was PCR amplified from pQCD2qt (Ding et al., 1996)
15 using the Pfu DNA polymerase (Stratagene) and cloned at
the PmeI site of pTMV-30B to yield pTMV-T2b. The
plasmid pTMV-TΔ2b1 was generated from pTMV-T2b by PCR
mutagenesis as previously described (Ding et al., 1995)
(incorporated herein by reference). Two nucleotide
20 substitutions (both C --> T) were introduced at
positions equivalent to nucleotides 2576 and 2582 of
TAV RNA2 (Moriones et al., 1991) and converted both
codons 44 (CAA) and 46 (CGA) of ORF 2b to stop codons
(TAA and TGA). The plasmid pTMV-TΔ2b2 contained the
25 same two nucleotide mutations as in pQCD2qt2 (Ding et
al., 1996) that changed the second codon of ORF 2b to a
stop codon. The coding sequence of CMV ORF 2b was
obtained from pSK2b (Ding et al., 1994) as a
BamHI-Asp718 fragment, which was end-filled and cloned
30 into the PmeI site of pTMV-30B to give pTMV-C2b.

Plasmids pTMV-TC1, pTMV-TC2, pTMV-TC3, pTMV-CT1,
pTMV-CT2 and pTMV-CT3: The previously described
mutagenesis protocol (Ding et al., 1996) (incorporated
herein by reference) that involves three separate PCRs

was used with templates pQCD2 (Ding et al., 1995) or pQCD2qt (Ding et al., 1996) to generate six chimaeric DNA fragments (Fig. 3). The final PCR fragments were cloned at the PmeI site of pTMV-30B to give the six plasmid constructs listed.

5 Plasmid pTMV-T2bC: Nucleotide substitutions, AA --> GT (equivalent to nucleotides 2508-2509 of TAV RNA 2) and CGA --> TCT (nucleotides 2529-2531 of TAV RNA 2) were introduced by PCR into the coding sequence of 10 Tav2b as encoded by pTMV-T2b. The resultant plasmid was called pTMV-T2bC.

15 Plasmids pPVX-T2b and pPVX-TΔ2b2: The inserted TAV sequence in pTMV-T2b and pTMV 2TΔ2b2 (Fig. 4) was obtained as an AgeI-XhoI fragment and cloned in the PVX vector pP2C2S.

2. In vitro transcription, plant infection and Northern blot analysis

Plasmid pTMV-30B and its derivatives were linearized by PstI whereas pPVX-T2b and pPVX-TΔ2b2 were 20 linearized by SpeI before they were transcribed in vitro in the presence of cap analog using T RNA polymerase (New England Biolabs). *N. tabacum* cv. Samsun (nn) plants were grown in Conviron growth chambers (22°C constant, 75% humidity and hours photoperiod). At approximately weeks old, the youngest 25 fully expanded leaves of the plants were dusted with carborundum and inoculated with the capped RNA transcripts (transcribed from 1μg plasmid DNA template/leaf). At various times after inoculation, 30 leaves were excised and immediately frozen in liquid nitrogen before total plant RNAs were extracted and analyzed by Northern blot analysis as previously described (Ding et al., 1995).

35 Induction and suppression of PTGS of the GFP transgene as well as GFP imaging in whole plant were

carried out as described previously (Brigneti et al., 1998). Briefly, GFP expressing seedlings from line 16c were infiltrated with *A. tumefaciens* carrying a binary Ti plasmid that contains a functional 35S-GFP cassette. 5 Three weeks after infiltration when systemic PTGS of the GFP transgene was complete, RNA transcripts from pPVX-T2b or pPVX-TΔ2b2 were inoculated to the youngest fully expanded leaves of the plants.

10 The following DNA fragments were labeled with α -³²P-dCTP by random priming as described (Sambrook et al., 1989). The SphI-StuI fragment from pTMV-30B corresponds to nucleotides 445 to 1675 of the TMV genome (Goelet et al., 1982). The probes specific for the mRNA of PR-1a (Cornelissen et al., 1987), and 15 PR- (Cornelissen et al., 1986), and for the 18S rRNA (Venkateswarlu and Nazar, 1991) were all obtained by PCR according to the published sequences and confirmed by sequencing. For Northern analyses, equal amounts of the total RNAs (Stg) were used for all samples and the 20 probe specific for 18S rRNA was employed to monitor RNA loading.

3. Virus progeny RNA analysis

25 The viral progeny RNAs were recovered from plants inoculated with each of the recombinant TMV transcripts and analyzed by RT-PCR and DNA sequencing. The cucumoviral 2b coding sequences cloned at the PmeI site of pTMV-30B were first amplified by RT-PCR using a pair of primers flanking the PmeI site of pTMV-30B. The 30 amplified fragments were then purified from agarose gels and either sequenced directly using the same pair of primers or cloned into a plasmid vector before sequencing.

Example 8

1. Induction of hypersensitive cell death

N. tabacum cv. Samsun (nn) does not contain the N gene and is thus susceptible to infection by many TMV strains, including U1 and U5 (Mathews, 1991).

Systemically infected plants show characteristic leaf mosaic symptoms. The vector pTMV-30B (Fig. 4) is similar to the TMV-based *in planta* expression vectors previously described (Donson et al., 1991; Kumagai et al., 1995), except that expression of the inserted foreign gene was driven by the 22 U1 coat protein (CP) subgenomic RNA (sgRNA) promoter (arrow 2, Fig. 4) whereas the CP gene and its sgRNA promoter (arrow 3, Fig. 1) were obtained from the U5 strain (W.O. Dawson, unpublished data). The recombinant viral RNA transcribed from pTMV-30B was named TMV-30B. This nomenclature system is used throughout the text. TMV-30B infected Samsun plants displayed a milder systemic mosaic than did Samsun plants infected with the U1 strain of TMV.

The coding sequences of Tav2b and Cmv2b were cloned downstream of the U1 sgRNA promoter of pTMV-30B to give pTMV-T2b and pTMV-C2b (Fig. 4), respectively. Local necrotic lesions, a morphological marker of the HR, appeared on the tobacco leaf inoculated with TMV-T2b about three days post-inoculation (dpi) whereas the rest of the plant remained symptomless for as long as observations were made (five weeks). In contrast, TMV-C2b did not induce necrotic lesions on the inoculated leaf, and produced mosaic symptoms on the upper uninoculated systemic leaves. These latter symptoms were similar to those caused by infection with TMV-30B.

To determine the distribution pattern of TMV-T2b and TMV-C2b in the inoculated tobacco plants, total RNAs were extracted from the inoculated and systemic

leaves and analyzed by Northern blot hybridization using a probe specific to the genomic RNA of TMV (indicated on the right of Fig. 5). Similarly high levels of accumulation of genomic RNAs were detected in 5 both the inoculated leaves (top panel) and the systemic leaves (middle panel) of the plants that were inoculated with either TMV-30B (lane TMV) or TMV-C2b (lane C2b). In comparison, a much lower level of TMV-T2b accumulated in the inoculated leaves (lane T2b, top panel) and no accumulation was detected in the 10 systemic leaves (lane T2b, middle panel). The presence of the coding sequence of Tav2b or Cmv2b in the progeny viral RNAs extracted from the inoculated leaves was confirmed using sequence-specific probes and by 15 sequencing the cDNA fragments obtained from reverse transcription - polymerase chain reaction (RT-PCR). In addition, the genomic RNAs of TMV-C2b and TMV-T2b migrated more slowly than the corresponding genomic RNA of TMV-30B during denaturing agarose gel 20 electrophoresis (Fig. 5, compare lane TMV with the four lanes next to it). Thus, the expression of Tav2b induces hypersensitive cell death and strong virus resistance in the Samsun tobacco cultivar. In contrast, Cmv2b is inactive in this manner.

25 2. PR gene expression and virus resistance by Tav2b

To test whether or not the challenge inoculation 30 of TMV-T2b also lead to transcriptional induction of genes encoding the PR proteins - molecular markers associated with disease resistance responses, total RNAs extracted from the tobacco leaves at different time points following TMV-T2b inoculation were subjected to Northern blot analysis using probes 35 specific for PR-1a mRNA or PR-5 mRNA. As shown in Fig. 6, the synthesis of both PR-1a (top panel) and PR-5

(lower panel) mRNAs was detectable three dpi and reached maximums of steady-state RNA at five (PR-1a) and seven (PR-5) dpi, respectively. The timing of mRNA induction at three dpi coincided with the appearance of 5 macroscopic necrotic lesions. In contrast, the transcription of PR-1a mRNA (Fig. 5, lower panel) and PR-5 mRNA was not significantly induced in plants infected by TMV-30B (Fig. 5, lane TMV) or TMV-C2b (Fig. 5, lane C2b) even at ten dpi (or at any other earlier 10 time points). Thus, the challenge inoculation by TMV-T2b also led to the transcriptional induction of PR-1a and PR-5 genes. The hypersensitive cell death, PR gene expression and strong virus resistance induced by Tav2b in the Samsun cultivar are the typical host 15 responses associated with the gene-for-gene disease resistance mechanism. Thus, these results indicate that Tav2b, when expressed from the TMV genome, functions as an Avr gene.

Example 9

20 (Full-Length Sequence Requirement for Avr Activity)

Point mutations were introduced into the coding sequence of Tav2b in the plasmid pTMV-T2b to give pTMV-T Δ 2b1 and pTMV-T Δ 2b2 (Fig. 4). The recombinant virus TMV-T Δ 2b2 was not expected to yield any Tav2b 25 product in infected plants because the second codon (GCA) was converted to a stop codon (TAA). In pTMV-T Δ 2b1 both codons 44 (CAA) and 46 (CGA) of Tav2b were changed to stop codons (TAA and TGA). Neither TMV-T Δ 2b1 nor TMV-T Δ 2b2 induced the formation of 30 necrotic lesions in the inoculated leaves and the inoculated plants developed systemic mosaic symptoms similar to those caused by TMV-C2b. Both TMV-T Δ 2b1 and TMV-T Δ 2b2 accumulated to detectable levels in the

inoculated leaves and systemic leaves, as revealed by Northern blot hybridization (Fig. 5, top and middle panels, lanes TΔ2b1 and TΔ2b2). Progeny analysis by RT-PCR and sequencing showed that the introduced mutations in both TMV-TΔ2b1 and TMV-TΔ2b2 were stably maintained and no second-site mutations were detected in the inserted TAV sequence. Furthermore, unlike TMV-T2b, infection by TMV-TΔ2b1 or TMV-TΔ2b2 did not lead to the transcriptional induction of PR-1a (Fig. 5, bottom panel, lanes TΔ2b1 and TΔ2b2; Fig. 6, left four lanes) or PR-5 (data not shown) genes. Thus, the induction of hypersensitive cell death, PR gene expression and strong virus resistance in the Samsun cultivar by TMV-T2b correlates with the ability of TMV-T2b to encode the full-length translatable Tav2b open reading frame. This suggests that the encoded protein, Tav2b, is the active molecule and the observed Avr activity is not related to the inserted TAV RNA sequence. This suggestion is also supported by a loss of the Avr activity observed for a mutant form of Tav2b, T2bC (see below), which contained nucleotide substitutions introduced at positions different to those occurred in TΔ2b1 and TΔ2b2. Furthermore, as TMV-TΔ2b1 infected the Samsun cultivar systemically, expression of the truncated Tav2b of 44 amino acids (aa) must be insufficient to elicit the resistance responses.

Example 10

(Functional domains of the Tav2b protein)

The above experiments of Examples 7 & 8 indicated that Tav2b, when expressed in *cis* from the TMV vector, induced hypersensitive cell death and strong virus resistance in the Samsun (nn) tobacco cultivar.

However, Cmv2b is not active in this manner when similarly expressed from the TMV genome. Cmv2b and Tav2b are encoded by two different virus species from the same *Cucumovirus* genus (Ding et al., 1994; Shi et al., 1997). The predicted amino acid sequences of the two proteins are 24% identical (46.2% similarity), the least conserved pair among the known cucumoviral 2b proteins (Ding et al., 1994). As the Tav2b protein is only 95 aa long, results from deletion mutants such as TMV-TΔ2b1 may not be informative in mapping functional domains of Tav2b. Thus, Tav2b as encoded by pTMV-T2b was progressively replaced from either the N-terminus (pTMV-CT1, 2, and 3) or the C-terminus (pTMV-TC1, 2, and 3) by the equivalent regions of Cmv2b according to the alignment of the known cucumoviral 2b proteins (Ding et al., 1994). The structures of the resultant 2b chimeras are given in Fig. 3. Regions (shown as numbers of aa) derived from Tav2b are depicted as open sections and those from Cmv2b depicted as filled sections.

Results of the infectivity experiments using the recombinant TMV transcripts from the six chimaeric 2b constructs are shown in Fig. 7 and summarized in Fig. 3. CT1, CT2 and CT3 resulted from the replacements of the N-terminal 91, 69 or 50 aa of Tav2b by the equivalent regions of Cmv2b (Fig. 3). The tobacco plants were susceptible to all three of the TMV recombinants in which the N-terminal 50 aa or more of the encoded 2b protein were derived from Cmv2b (TMV-CT1, 2, and 3). None of these recombinants induced necrotic lesions (data not shown) and all accumulated in both the inoculated and systemic leaves (Fig. 7, lanes CT1, CT2 and CT3). The infected plants also displayed systemic mild mosaic symptoms similar to those caused by TMV-C2b. Thus, absence of

the Tav2b N-terminal 50 aa in a 2b chimera resulted in the loss of the avirulence function, indicating that this region is essential for the induction of virus resistance and hypersensitive cell death in the host.

5 Consistent with the above observation, the data obtained from three TMV-TC recombinants further indicated that the Tav2b N-terminal sequence of 69 aa was sufficient to confer virus resistance in cv. Samsun. TC1, TC2 and TC3 resulted from the 10 replacements of the C-terminal 4, 26 or 50 aa of Tav2b by the equivalent regions from Cmv2b (Fig. 3). The N-terminal 69 and 91 aa respectively of TC1 and TC2 were derived from Tav2b (Fig. 3). Both induced strong virus resistance in the challenged tobacco plants. 15 This is because both TMV-TC1 and TMV-TC2 accumulated to very low levels in the inoculated leaves (Fig. 7, lanes TC1 and TC2 of the upper panel) and no accumulation of viral RNAs was detected in the systemic leaves (lanes TC1 and TC2 of the lower panel). The challenged plants 20 remained symptomless for as long as observations were made (five weeks). Reprobing the filter shown at the upper panel of Fig. 7 with the PR-1a probe showed that transcription of PR-1a mRNA was induced in the tobacco leaves inoculated with TMV-TC1 and TMV-TC2 but not in 25 those inoculated with the remaining four viruses. Thus, the function of the N terminal 69 aa of Tav2b in resistance activation is independent of its remaining 26 amino acids at the C-terminus.

TC3 contained 50 aa from the N-terminus of the 30 Tav2b protein (Fig. 3) and did not induce virus resistance because TMV-TC3, like TMV-CT3, infected the tobacco plants systemically (Fig. 7, bottom panel). This result is consistent with the finding of Example 9 that TΔ2b1, encoding a truncated Tav2b of 44 aa, did 35 not induce virus resistance in the tobacco plants. The

fact that TC2, but not TC3, is avirulent (Fig. 3) suggests that amino acids 50 - 69 of Tav2b play a key role in the resistance activation. However, CT3 contained the same 20 aa from Tav2b, but it failed to 5 induce virus resistance (Fig. 7), indicating that presence in a 2b chimera of this region of Tav2b, unlike the more extended N-terminal region of 69 aa, is not sufficient to activate virus resistance.

Although the Samsun cultivar is resistant to both 10 TMV-TC1 and TMV-TC2, TMV-TC1 induced necrotic lesions in the inoculated leaves identical to those triggered by TMV-T2b. Under the same conditions, TMV-TC2 caused no visible hypersensitive cell death (Fig. 3). This result, a local and symptomless infection by TMV-TC2, 15 was consistent and reproducible in six independent experiments, involving a total of 37 plants. This indicates that the sequence encompassing amino acids 70-91 of Tav2b is required for triggering hypersensitive cell death. However, TMV-CT2 and 20 TMV-CT3, both of which encode the same 22 amino acids from Tav2b, did not cause necrotic lesions (Fig. 3), suggesting that this sequence alone is insufficient to trigger hypersensitive cell death.

Example 11

25 (Abolishment of Tav2d avirulence activity)

To further analyze the avirulence determinant, 21 Lys and 27 Arg, both positively charged and located within the resistance domain of the avirulent Tav2b, were replaced with 21 Val and 27 Ser found at the aligned 30 positions of the virulent Cmv2b (Ding et al., 1994). TMV-T2bC, expressing the resultant Tav2b mutant, did not elicit any of the disease resistance responses associated with wild type Tav2b. Neither necrotic

lesions nor transcriptional induction of PR 1a mRNA were observed in the inoculated Samsun leaves. Furthermore, the TMV-T2bC inoculated plants became systemically infected. Northern blot analysis showed 5 that TMV-T2bC accumulated to similar levels to TMV-TΔ2b2 in both the inoculated and the systemic leaves of the infected plants. RT-PCR and DNA sequencing showed that the introduced mutations were maintained in the progeny viral genome and no 10 additional mutations were found in the Tav2b coding sequence of TMV-T2bC. Thus, the two aa substitutions abolished the Avr activity of Tav2b in this tobacco cultivar.

Example 12

15 (Tav2b activity in *N. benthamiana*)

We have established previously that Cmv2b expressed from a potato virus X (PVX) vector functions as a virulent determinant and suppresses PTGS of a green fluorescent protein (GFP) transgene in *N. benthamiana* plants (Brigneti et al., 1998). *N. benthamiana* plants were also fully susceptible to TMV-T2b. Infected plants displayed a systemic necrosis and began to collapse at 14 dpi and died a few days after. TMV-C2b induced a much milder systemic 20 infection that did not resulted in the death of the infected plants; this difference in virulence between Tav2b and Cmv2b has been observed previously (Ding et al., 1996). Plants systemically infected with TMV-TΔ2b2 showed a mild chlorosis similar to that 25 caused by TMV-30B infection. Accumulation of TMV-T2b and TMV-TΔ2b2 in both the inoculated and systemic leaves were confirmed by Northern blot hybridization.

Thus, Tav2b, like Cmv2b, was not recognized as an Avr gene in *N. benthamiana*.

To test the role of Tav2b in suppressing PTGS, the TAV sequences from pTMV-T2b and pTMV-T Δ 2b2 were transferred into a PVX vector (pP2C2S) to give pPVX-T2b and pPVX-T Δ 2b2, from which RNA transcripts were obtained and inoculated to *N. benthamiana* plants exhibiting complete systemic PTGS of the GFP transgene. PVX-T2b was similarly virulent to TMV-T2b in *N. benthamiana* and PVX-T2b infection led to a rapid death of the infected plants. However, at 12 dpi when the severe systemic necrosis had not developed, the newly emerging leaves of PVX-T2b-infected plants were green fluorescent under UV illumination, whereas old leaves that developed prior to virus infection remained red fluorescent. Northern analysis of RNA extracted at 12 dpi showed a significant level of GFP RNA accumulation in these green fluorescent leaves. By comparison, at 12 dpi, PVX-C2b-infected plants remained red fluorescent and had 1 GFP RNA levels that were below the limit of detection although the newly emerging leaves of those plants became green fluorescent and accumulated high levels of GFP RNA a few days after (Brigneti et al., 1998). As expected, PVX-T Δ 2b2 was much less virulent than PVX-T2b in *N. benthamiana* and no suppression of PTGS of the GFP transgene was observed in PVX-T Δ 2b2-infected plants at 18 dpi or at 35 dpi. Thus, Tav2b is a virulent determinant and a suppressor of PTGS in *N. benthamiana*.

REFERENCES

Anandalakshmi, R., Pruss, G.J., Ge, X., Marathe, R.,
Mallory, A.C., Smith, T.H. and Vance, V.B. (1998) A
viral suppressor of gene silencing in plants. *Proc.*
5 *Natl. Acad. Sci. USA.*, **95**, 13079-13084.

Baker, B., Zambryski, P., Staskawicz, B. and Dinesh-
Kumar, S.P. (1997) Signaling in plant-microbe
interactions. *Science*, **276**, 726-733.

Bendahmane, A., Kohn, B.A., Dedi, C. and Baulcombe, D.C.
10 (1995) The coat protein of potato virus X is a
strain-specific elicitor of Rxl-mediated virus
resistance in potato. *Plant J.*, **8**, 933-941.

Berzal-Herranz, A., de la Cruz, A., Tenllado, F.,
Diaz-Ruiz, J.R., Lopez, L., Sanz, A.I., Vaquero, C.,
15 Serra, M.T. and Garcia-Luque, I. (1995) The capsicum L3
gene-mediated resistance against the tobamoviruses is
elicited by the coat protein. *Virology*, **209**, 498-505.

Brigneti, G., Voinnet, O., Li, W.X., Ji, L.H., Ding,
S.W. and Baulcombe, D.C. (1998) Viral pathogenicity
20 determinants are suppressors of transgene silencing in
Nicotiana benthamiana. *EMBO J.*, **17**, 6739-6746.

Caboche (1990). *Physiol. Plant.* **79**:173-176.

Chapman, S., Kavanagh, T. and Baulcombe, D. (1992)
Potato virus X as a vector for gene expression in
25 plants. *Plant J.*, **2**, 549-557.

Christou et al. (1991) *Bio/Technology* **9**:957-962.

Cornelissen, B.J. et al. (1987). Structure of tobacco genes encoding pathogenesis-related proteins from the PR-1 group. *Nucleic Acids Research*, **15**, 6799-6811.

5 Cornelissen, B.J., Hooft van Huijsduijnen, R.A. and Bol, J.F. (1986) A tobacco mosaic virus induced tobacco protein is homologous to the sweet-tasting protein thaumatin. *Nature*, **321**, 531-532.

10 Covey, S.N., Al-Kaff, N.S., Langara, A. and Turner, D.S. (1997) Plants combat infection by gene silencing. *Nature*, **385**, 781 -782.

Cronin, S., Verchot, J., Haldeman-Cahill, R., Schaad, M.C. and Carrington, J.C. (1995) Long distance movement factor: a transport function of the potyvirus helper component proteinase. *Plant Cell*, **7**, 549-559.

15 Culver, J.N., and Dawson, W.O. (1991) Tobacco mosaic virus elicitor coat protein genes produce a hypersensitive phenotype in transgenic *Nicotiana sylvestris* plants. *Mol. Plant Microbe Interact.*, **4**, 458-463.

20 Datta et al. (1990) *Bio/Technol.* **8**:736-740.

Depicker, A. And Van Montagu, M. (1997) Post-transcriptional gene silencing in plants. *Curr. Opin. Cell Biol.*, **9**, 372-382.

25 Ding, SW., Anderson, BJ., Haase, HR. and Symons, RH. (1994). New overlapping gene encoded by the cucumber mosaic virus genome. *Virology*, **198**, 593-601.

Ding, SW., Li, W X. and Symons, RH. (1995). A novel naturally occurring hybrid gene encoded by a plant RNA virus facilitates long distance virus movement. *EMBO J.*, **14**, 5762-5772.

5 Ding, SW., Shi, BJ., Li, WX. and Symons, RH. (1996). An interspecies hybrid RNA virus is significantly more virulent than either parental virus. *Proc. Nat'l Acad. Sci. USA*, **93**, 7470-7474.

10 Donson, J., Kearney, C.M., Hilf, M.E. and Dawson, W.O. (1991) Systemic expression of a bacterial gene by a tobacco mosaic virus-based vector. *Proc. Natl. Acad. Sci. USA*, **88**, 7204 32 7208.

15 Gilbert, J., Spillane, C., Kavanagh, T.A. and Baulcombe, D.C. (1998) Elicitation of Rx mediated resistance to PVX in potato does not require new RNA synthesis and may involve a latent hypersensitive response. *Mol. Plant-Microbe Interact.*, **11**, 833-835.

20 Goelet, P., Lomonossoff, G.P., Butler, P.J. Akam, M.E., Gait, M.J. and Karn, J. (1982) Nucleotide sequence of tobacco mosaic virus RNA. *Proc. Natl. Acad. Sci. USA*, **79**, 5818-5822.

25 Gopalan, S., Bauer, D.W., Alfano, J.R., Loniello, A.O., He, S.Y. and Collmer,A. (1996) Expression of the *Pseudomonas syringae* avirulence protein AvrB in plant cells alleviates its dependence on the hypersensitive response and pathogenicity(Hrp) secretion system in eliciting genotype-specific hypersensitive cell death. *Plant Cell*, **8**, 1095-1105.

Guo, H.S. and Garcia, J.A. (1997) Delayed resistance to plum pox potyvirus mediated by a mutated RNA replicase gene: involvement of a gene-silencing mechanism. *Mol. Plant Microbe Interact.*, **10**, 160-170.

5 Hammond-Kosack, K.E. and Jones, J.D.G. (1996) Resistance gene-dependent plant defense responses. *Plant Cell*, **8**, 1773-1791.

Hammond-Kosack, K.E. and Jones, J.D.G. (1997) Plant disease resistant genes. *Annu. Rev. Plant Physiol.*
10 *Plant Mol. Biol.*, **48**, 575-607.

Hammond-Kosack, K.E., Silverman, P., Raskin, I. and Jones, J.D.G. (1996) Race-specific elicitors of *Cladosporium fulvum* induce changes in cell morphology and the synthesis of ethylene and salicylic acid in
15 tomato plants carrying the corresponding Cf disease resistance genes. *Plant Physiol.*, **110**, 1381-1395.

Kasschau, K.D. and Carrington, J.C. (1998) A counterdefensive strategy of plant viruses: Suppression of posttranscriptional gene silencing. *Cell*, **95**,
20 461-470.

Keen, N.T. (1990) Gene-for-gene complementarity in plant-pathogen interactions. *Annu. Rev. Genet.*, **24**, 447-463.

25 Kim, C-H. and Palukaitis, P. (1997) The plant defense response to cucumber mosaic virus in cowpea is elicited by the viral polymerase gene and affects virus accumulation in single cells. *EMBO J.*, **16**, 4060-4068.

Knogge, W. (1996) Fungal infection of plants. *Plant Cell*, **8**, 1711-1722.

5 Kumagai, M.H., Donson, J., Della-Cioppa, G., Harvey, D., Hanley, K. and Grill, L.K. (1995) Cytoplasmic inhibition of carotenoid biosynthesis with virus-derived RNA. *Proc. Natl. Acad. Sci. USA.*, **92**, 1679-1683.

10 Kumagai, M.H., Turpen, T.H. Weinezettl, N., Della-Cioppa, G., Turpen, A.M., Donson, J., Hilf, M.e., Grantham, G.L., Dawson, W.O., Chow, T.P., Piatak, M. And Grill, L.K. (1993). Rapid, high level expression of biologically active a-trichosanthin in transfected plants by an RNA viral vector. *Proc. Nat'l Acad. Sci. USA*, **90**, 427-430.

15 Lamb, C. and Dixon, R.A. (1997) The oxidative burst in plant disease resistance. *Annu. Rev. Plant Physiol. Plant Mol. Biol.*, **48**, 251-275.

Leach, J.E. and White, F.F. (1996) Bacterial avirulence genes. *Annu. Rev. Phytopathol.*, **34**, 153-179.

20 Ledoux et al., (1974) *Nature*, **249**:17-21).

25 Leister, R.T., Ausubel, F.M. and Katagiri, F. (1996) Molecular recognition of pathogen attack occurs inside of plant cells in plant disease resistance specified by the *Arabidopsis* gene *RPS2* and *RPM1*. *Proc. Natl. Acad. Sci USA.*, **93**, 15497-15502.

Lindbo, J.A., Silva-Rosales, L., Proebsting, W.M. and Dougherty, W.G. (1993) Induction of a highly specific

antiviral state in transgenic plants: implications for regulation of gene expression and virus resistance. *Plant Cell*, 5, 1749-1759.

5 Lindgren, P.B. (1997) The role of *hrp* genes during plant-bacterial interactions. *Annu. Rev. Phytopathol.*, 35, 129-152.

10 Malamy, J., Henning, J., and Klessig, D. F. (1992). Temperature-dependent induction of salicylic acid and its conjugates during the resistance response to tobacco mosaic virus infection. *Plant Cell*, 4, 359-366.

Matthews, R.E.F. (1991) *Plant Virology*, 3rd edition. Academic Press, New York.

15 Meshi, T., Motoyoshi, F., Maeda, T., Yoshiwoka, S., Watanabe, H. and Okada, Y. (1989) Mutations in the tobacco mosaic virus 30-kD protein gene overcome Tm-2 resistance in tomato. *Plant Cell*, 1, 515-522.

20 Meshi, T., Motoyoshi, F., Adachi, A., Watanabe, Y., Takamatsu, N. and Okada, Y. (1988) Two concomitant base substitutions in the putative replicase genes of tobacco mosaic virus confer the ability to overcome the effects of a tomato resistance gene, Tm-1. *EMBO J.*, 7, 1575-1581.

25 Metraux, J. P., Singer, H., Rayals, J., Ward, E., Wyss-Benz, M., Gaudin, J., Raschdorf, K., Schmid, E., Blum, W., and Inverardi, B. (1990). Increase in salicylic acid at the onset of systemic acquired resistance in cucumber. *Science*, 250, 1004-1006.

Moriones, E., Roossinck, M.J. and Garcia-Arenal, F. (1991) Nucleotide sequence of tomato aspermy virus RNA2. *J. Gen. Virol.*, **72**, 779-783.

Padgett, H.S., Watanabe, Y. and Beachy, R.N. (1997) 5 Identification of the TMV replicase sequence that activates the N gene-mediated hypersensitive response. *Mol. Plant-Microbe Interact.*, **10**, 709-715.

Pirhonen, M.U., Lidell, M.C., Rowley, D.L., Lee, S.W., Jin, S., Liang, Y., Silverstone, S., Keen, N.T. and 10 Hutcheson, S.W. (1996) Phenotypic expression of *Pseudomonas syringae* avr genes in *E. coli* is linked to the activities of the *hrp*-encoded secretion system. *Mol. Plant Microbe Interact.*, **9**, 252-260.

Ratcliff, F., Harrison, B.D. and Baulcombe, D.C. (1997) 15 A similarity between viral defense and gene silencing in plants. *Science*, **276**, 1558-1560.

Rhodes et al., (1988) *Science*, **240**:204-207).

Ross, A. F. (1961). Systemic acquired resistance induced by localized virus infection in plants. 20 *Virology*, **14**, 340-358.

Ruiz, M.T., Voinnet, O. and Baulcombe, D.C. (1998) Initiation and maintenance of virus 36 induced gene silencing. *Plant Cell*, **10**, 937-946.

Ryals, J.A., Neuenschwander, U.H., Willits, M.G., 25 Molina, A., Steiner, H.Y. and Hunt, M.D. (1996) Systemic acquired resistance. *Plant Cell*, **8**, 1809-1819.

5 Sambrook, J., Fritsch, E.F. and Maniatis, T. (1989) *Molecular Cloning: A Laboratory Manual.* Cold Spring Harbor Press, Cold Spring Harbor, NY.

10 5 Scofield, S.R., Tobias, C.M., Rathjen, J.P., Chang, J.H., Lavelle, D.T., Michelmore, R.W. and Staskawicz, B.J. (1996) Molecular basis of gene-for-gene specificity in bacterial speck disease of tomato. *Science*, **274**, 2063-2065.

15 Shi, BJ., Ding, SW. and Symons, RH. (1997). In vivo expression of an overlapping gene encoded by the cucumoviruses. *J. Gen. Virol.*, **78**, 237-241.

Shimamoto et al., (1989) *Nature*, **338**:274-277

15 Sticher, L., Mauch-Mani, B. and Metraux, J.P. (1997) Systemic acquired resistance. *Annu. Rev. Phytopathol.*, **35**, 235-270.

20 Tang, X., Frederick, R.D., Zhou, J., Halterman, D.A., Jia, Y. and Martin, G.B. (1996) Initiation of plant disease resistance by physical interaction of avrPto and Pto kinase. *Science*, **274**, 2060-2063.

20 Taraporewala, Z.F. and Culver, J.N. (1996) Identification of an elicitor active site within the three-dimensional structure of the tobacco mosaic tobamovirus coat protein. *Plant Cell*, **8**, 169-178.

25 Topfer, R. et al., (1989) *Plant Cell*, **1**:133-139.

25 Toriyama et. al., (1988) *Bio/Technol.*, **6**:1072-1074

Van den Ackerveken, G., Marois, E. and Bonas, U. (1996) Recognition of the bacterial avirulence protein AvrBs3 occurs inside the host plant cell. *Cell*, **87**, 1307-1316.

5 Venkateswarlu, K. and Nazar, R. (1991) A conserved core structure in the 18-25S rRNA intergenic region from tobacco, *Nicotiana rustica*. *Plant Mol. Biol.*, **17**, 189-194.

10 Ward, E. R., Uknnes, S. J., Williams, S. C., Dincher, S. S., Widerhold, D. L., Alexander, D. C., Ahl-Goy, P., Metraux, J-P., and Ryals, J. A. (1991). Coordinate gene activity in response to agents taht induce systemic acquired resistance. *Plant Cell*, **3**, 1085-1094.

15 Weber, H., Schultze, S. and Pfitzner, A.J. (1993) Two amino acid substitutions in the tomato mosaic virus 30-kilodalton movement protein confer the ability to overcome the Tm-2(2) resistance gene in the tomato. *J Virol.*, **67**, 6432-6438.

20 Whitham, S., Dinesh-Kumar, S.P., Choi, D., Hehl, R., Corr, C. and Baker, B. (1994) The product of the tobacco mosaic virus resistance gene N: Similarity to Toll and the interleukin-1 receptor. *Cell*, **78**, 1101-1115.

25 Yang, Y., Shah, J. and Klessig, D.F. (1997) Signal perception and transduction in plant defense responses. *Genes Dev.*, **11**, 1621-1639.

Zhang W. et. al., (1988) *Theor. Appl. Genet.*, **76**:835-840.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Ding, Shou-wei

(ii) TITLE OF INVENTION: DISEASE RESISTANT TRANSGENIC PLANTS

(iii) NUMBER OF SEQUENCES: 4

(iv) CORRESPONDENCE ADDRESS:

(A) ADDRESSEE: Rothwell, Figg, Ernst & Kurz
(B) STREET: 555 Thirteenth Street, N.W., Suite 701 East
(C) CITY: Washington
(D) STATE: DC
(E) COUNTRY: USA
(F) ZIP: 20004

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk
(B) COMPUTER: IBM PC compatible
(C) OPERATING SYSTEM: PC-DOS/MS-DOS
(D) SOFTWARE: PatentIn Release #1.0, Version #1.30

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER:
(B) FILING DATE:
(C) CLASSIFICATION:

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: Figg, Edward A.
(B) REGISTRATION NUMBER: 27,195
(C) REFERENCE/DOCKET NUMBER: 2248-108

(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: 202-783-6040
(B) TELEFAX: 202-783-6031

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 328 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Tomato aspermy virus

(vii) IMMEDIATE SOURCE:

(B) CLONE: pTMV-30B

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

ACCGTTAAGA AGAAGAAGAA TGGCAAGCAT CGAGATCCCT CTACACGAGA TCATTCGAAA	60
GTTGGAACGG ATGAATCAAA AGAAACAAGC ACAGAGGAAA CGACACAAAC TGAACCGCAA	120
GGAGCGGGGT CACAAAAGTC CAAGTGAACA AAGGCGATCG GAGTTATGGC ACGCGCGTCA	180
AGTTGAACCTT TCTGCCATTA ATTCCGATAA TTCTTCAGAT GAGGCTACCA CTCTGTGTCG	240
CTTGACACA TTTGGTTCCA AGTCTGATGC TATTTGTGAT CGCTCTGACT GGTGTCTCGA	300
TCAATGATTT CCGACCCCTTC GTCGTCCG	328

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 328 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- (A) DESCRIPTION: /desc = "Synthetic DNA"

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Tomato aspermy virus

(vii) IMMEDIATE SOURCE:

- (B) CLONE: pTAVd2b1

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

ACCGTTAAGA AGAAGTAAAGAA TGTAAGCAT CGAGATCCCT CTACACGAGA TCATTCGAAA	60
GTTGGAACGG ATGAATCAAA AGAAACAAGC ACAGAGGAAA CGACACAAAC TGAACCGCAA	120
GGAGCGGGGT CACAAAAGTC CAAGTGAACA AAGGCGATCG GAGTTATGGC ACGCGCGTCA	180
AGTTGAACCTT TCTGCCATTA ATTCCGATAA TTCTTCAGAT GAGGCTACCA CTCTGTGTCG	240
CTTGACACA TTTGGTTCCA AGTCTGATGC TATTTGTGAT CGCTCTGACT GGTGTCTCGA	300
TCAATGATTT CCGACCCCTTC GTCGTCCG	328

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 328 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- (A) DESCRIPTION: /desc = "Synthetic DNA"

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Tomato aspermy virus

(vii) IMMEDIATE SOURCE:
(B) CLONE: pTAVd2b2

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

ACCGTTAAGA AGAAGTAGAA TGTAAAGCAT CGAGATCCCT CTACACGAGA TCATTCGAAA	60
GTTGGAACGG ATGAATCAAA AGAAACAAGC ACAGAGGAAA CGACACAAAC TGAACCGCAA	120
GGAGCGGGGT CACAAAAGTC CAAGTGAATA AAGGTGATCG GAGTTATGGC ACGCGCGTCA	180
AGTTGAACTT TCTGCCATTA ATTCCGATAA TTCTTCAGAT GAGGGTACCA CTCTGTGTCG	240
CTTTGACACA TTTCCGTTCCA ACTCTGATGC TATTTGTGAT CGCTCTGACT GGTGTCTCGA	300
TCAATGATTT CCGACCCCTTC GTCGTCCG	328

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 504 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Cucumber mosaic virus

(vii) IMMEDIATE SOURCE:

(B) CLONE: pCMV2b

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

GATCCATGGA TGTGTTGACA GTAGTGGTGT CGACCGCCGA CCTCCACTTA GCCAATTGCG	60
AGGAGGTGAA ACGTCGAAGA CGAAGGTCTC ACGTCAGAAA CCGGCGAGCG AGGGGTTACA	120
AAAGTCCCAG CGAGAGAGCG CGATCTATAG CGAGACTTTT CCAGATGTTA CCATTCCACG	180
GAGTAGATCC CGTGGATTGG TTTCCCTGATG TCGTTCGCTC TCCGTCCGTT ACCAGCCTTG	240
TTTCTTATGA ATCTTTGAT GATACTGATT GGTTTGTGG TAACGAATGG GCCGAAGGGT	300
CGTTTGATT TCCGACCCCTT CGTCGTCCGA AGACGTTAAA CTACGCTCTC TTTATTGCGA	360
GTGCTGAGTT GGTAGTTGTC TCTAAACTAT CTGAAGTCGC TAAATCCATT ACTGGTTGCG	420
AACGGGTTGT CCATCCAGCT TACGGCTAAA ATGGTCAGTC ATGCCCAAA GGCATGCCGA	480
CACCCCTACAG GGTTGTGAG GTAC	504

CLAIMS

What is claimed is:

1. A transgenic plant stably transformed with a cucumovirus 2b gene or active fragment thereof operatively linked to a promoter that is capable of effecting expression of said gene in said plant when 5 said plant is infected with a pathogenic organism.
2. The transgenic plant of claim 1, wherein the cucumovirus 2b gene is one to which the nucleic acid of SEQ ID NO. 1 will hybridize under stringent conditions.
3. The transgenic plant of claim 1, wherein the cucumovirus 2b gene has substantially the sequence of SEQ ID NO. 1.
4. The transgenic plant of claim 1, wherein the plant is stably transformed with an active fragment of the cucumovirus 2b gene.
5. The transgenic plant of claim 4, wherein the fragment comprises a nucleic acid sequence encoding at least the 26 C-terminal amino acids of the protein encoded by the cucumovirus 2b gene.
6. The transgenic plant of claim 4, wherein the fragment comprises a nucleic acid sequence encoding at least the 45 C-terminal amino acids of the protein encoded by the cucumovirus 2b gene.
7. The transgenic plant of claim 4, wherein the fragment does not contain the amino acids encoding the 4 C-terminal amino acids of the protein encoded by the cucumovirus 2b gene.
8. The transgenic plant of claim 1, wherein expression of the 2b gene is controlled by a pathogen-inducible promoter.
9. The transgenic plant of claim 8, wherein the pathogen-inducible promoter is a PR protein gene promoter.

10. A method for rendering a plant resistant to disease caused by an infectious pathogenic agent, which comprises stably transforming the plant with a cucumovirus 2b gene or active fragment thereof 5 operatively linked to a promoter that is capable of effecting expression of said gene in said plant when said plant is infected with a pathogenic organism.

11. The method of claim 10, wherein the cucumovirus 2b gene is one to which the nucleic acid of SEQ ID NO. 1 will hybridize under stringent conditions.

12. The method of claim 10, wherein the cucumovirus 2b gene has substantially the sequence of SEQ ID NO. 1.

13. The method of claim 10, wherein the plant is stably transformed with an active fragment of the cucumovirus 2b gene.

14. The method of claim 13, wherein the fragment comprises a nucleic acid sequence encoding at least the 26 C-terminal amino acids of the protein encoded by the cucumovirus 2b gene.

15. The method of claim 13, wherein the fragment comprises a nucleic acid sequence encoding at least the 45 C-terminal amino acids of the protein encoded by the cucumovirus 2b gene.

16. The method of claim 13, wherein the fragment does not contain the amino acids encoding the 4 C-terminal amino acids of the protein encoded by the cucumovirus 2b gene.

17. The method of claim 10, wherein expression of the 2b gene is controlled by a pathogen-inducible promoter.

18. A seed of the transgenic plant of claim 1, 2, 3, 4, 5, 6, 7, 8 or 9.

19. A propagating part of the transgenic plant of claim 1, 2, 3, 4, 5, 6, 7, 8 or 9.

20. The transgenic plant of claim 1, which is corn, wheat, rice, millet, oat, barley, sorghum, sunflower, sweet potato, alfalfa, sugar beet, brassica species, tomato, pepper, soybean, tobacco, melon, squash, potato, peanut, pea, cotton or cacao.

21. An expression vector comprising a cucumovirus 2b gene or active fragment thereof operably linked to a plant-active promoter.

22. The expression vector of claim 21, wherein expression of cucumovirus 2b gene or active fragment thereof is controlled by a pathogen-inducible promoter.

23. The expression vector of claim 22, wherein the pathogen-inducible promoter is a PR protein gene promoter.

24. A transgenic plant stably transformed with a two-domain Avr gene having an inactive cell death domain, operatively linked to a promoter that is capable of effecting expression of said gene in said plant when said plant is infected with a pathogenic organism.

25. The transgenic plant of claim 24 wherein the Avr gene is derived from the cucumovirus 2b gene.

26. The transgenic plant of claim 25 wherein the Avr gene is a chimera of the resistance domain of the Tav2b gene and the cell death domain of the Cmv2b gene.

27. A method for rendering a plant resistant to disease caused by an infectious pathogenic agent, which comprises stably transforming the plant with a two-domain Avr gene having an inactive cell death domain, operatively linked to a promoter that is capable of effecting expression of said gene in said plant when said plant is infected with a pathogenic organism.

28. The method of claim 27 wherein the Avr gene is derived from the cucumovirus 2b gene.

29. The method of claim 27 wherein the Avr gene is a chimera of the resistance domain of the Tav2b gene and the cell death domain of the Cmv2b gene.

30. An expression vector comprising an Avr gene having an inactive cell death domain operably linked to a plant-active promoter.

31. The expression vector of claim 30 wherein the Avr gene is derived from the cucumovirus 2b gene.

32. The expression vector of claim 31 wherein the Avr gene is a chimera of the resistance domain of the Tav2b gene and the cell death domain of the Cmv2b gene.

33. The expression vector of claim 30, 31 or 32, wherein expression of the Avr gene is controlled by a pathogen-inducible promoter.

34. The expression vector of claim 33, wherein the pathogen-inducible promoter is a PR protein gene promoter.

35. A seed of the transgenic plant of claim 24, 25 or 26.

36. A propagating part of the transgenic plant of claim 24, 25 or 26.

37. The transgenic plant of claim 24, which is corn, wheat, rice, millet, oat, barley, sorghum, sunflower, sweet potato, alfalfa, sugar beet, brassica species, tomato, pepper, soybean, tobacco, melon, squash, potato, peanut, pea, cotton or cacao.

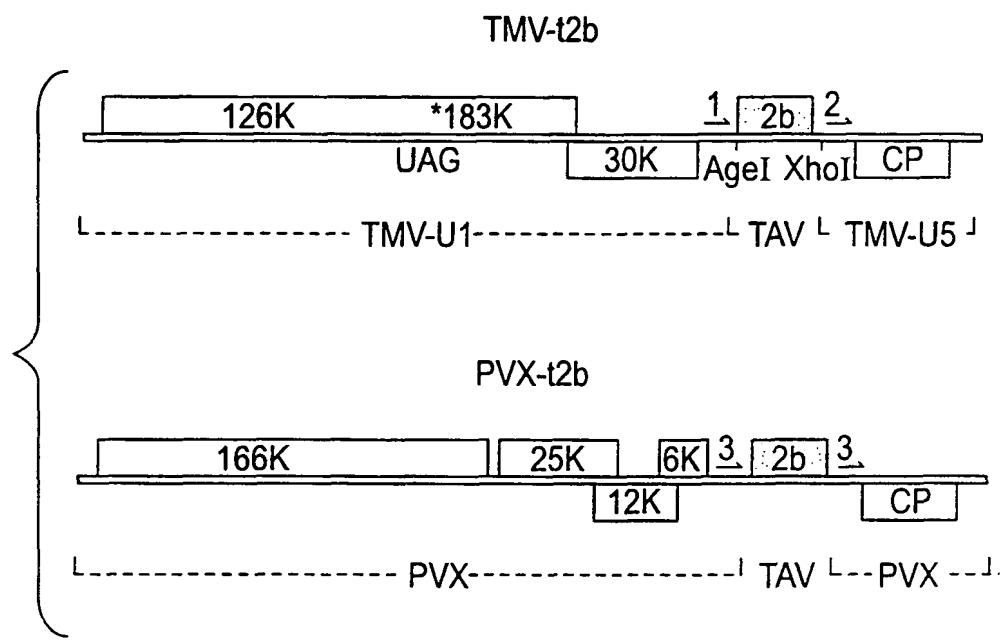


FIG. 1

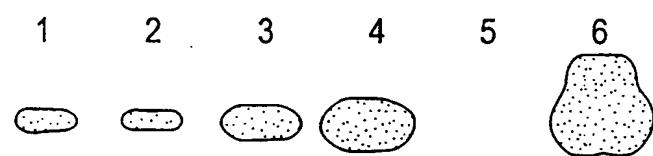


FIG. 2

TMV-	LENGTH (aa)	STRUCTURE (amino - carboxyl)	PLANT RESPONSE*
T2b	95	95	HR
TC1	102	91 11	HR
TC2	103	69 34	R
TC3	100	50 50	S
CT3	95	50 45	S
CT2	92	66 26	S
CT1	93	89 4	S
C2b	100	100	S

FIG. 3

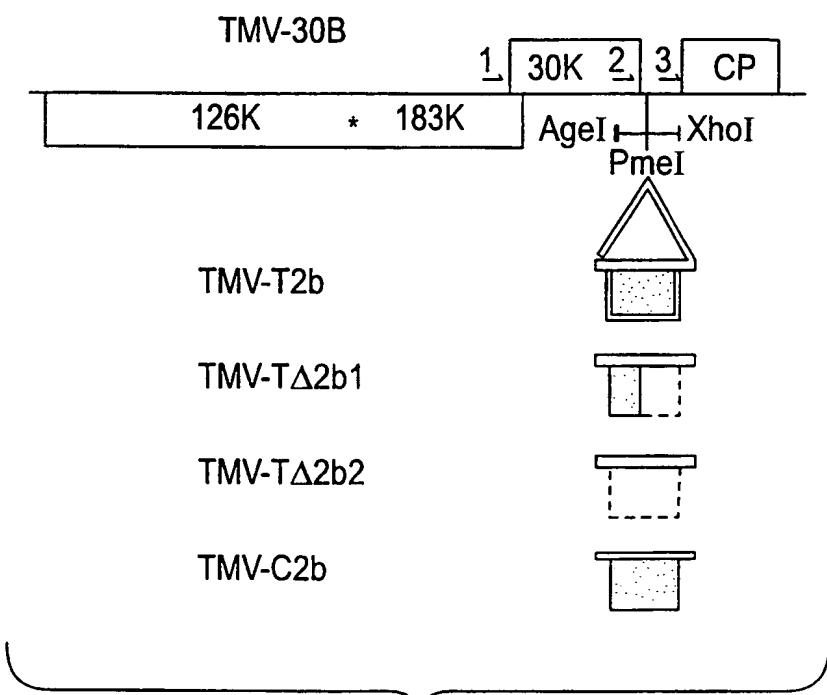


FIG. 4

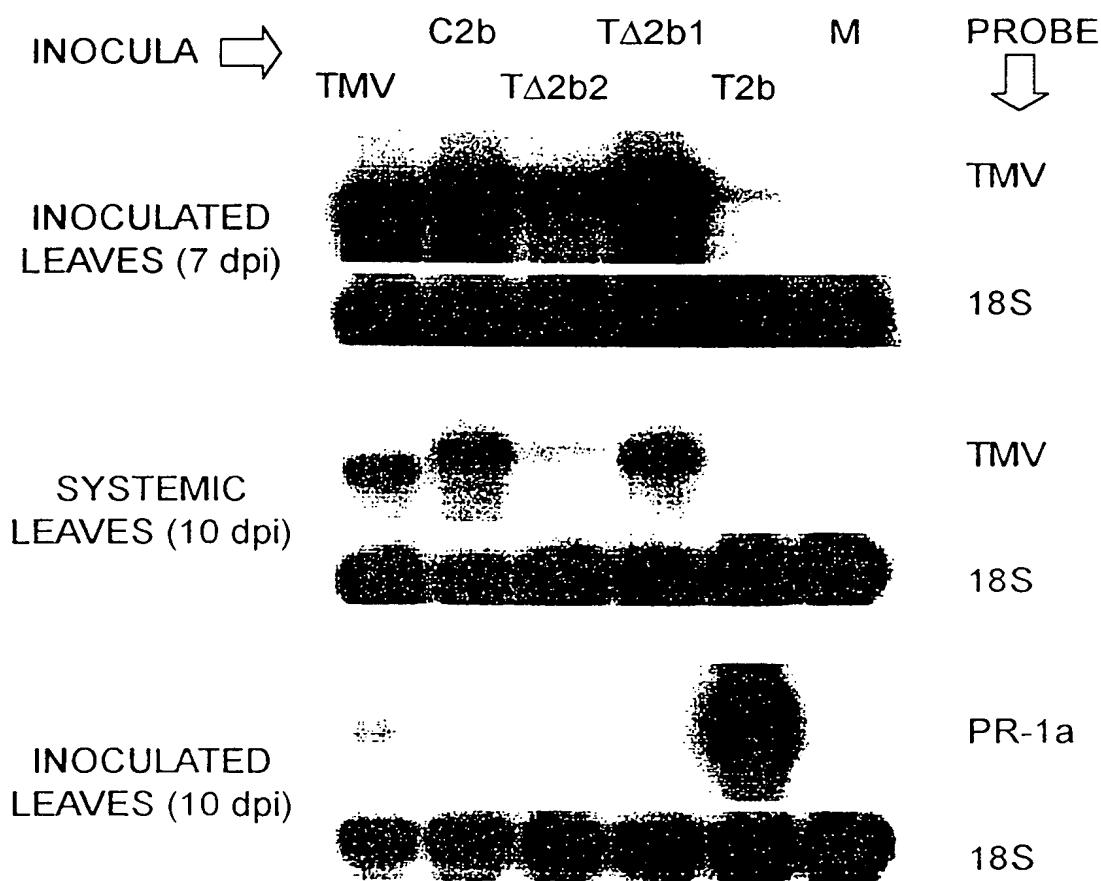


FIG. 5

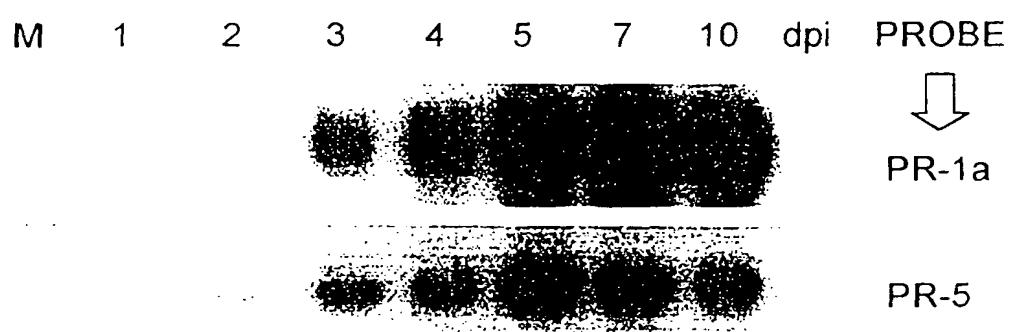


FIG. 6

7/7

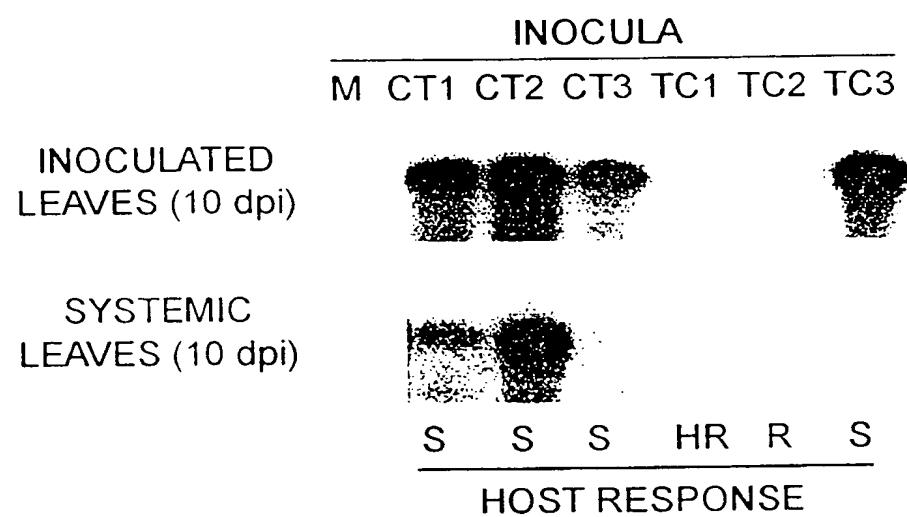


FIG. 7

INTERNATIONAL SEARCH REPORT

Int. Application No

PCT/SG 99/00012

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12N15/82 C07K14/08 C12N15/62 A01H5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>DING, S-W., ET AL.: "a novel naturally occurring hybrid gene encoded by a plant RNA virus facilitates long distance virus movement" THE EMBO JOURNAL, vol. 14, no. 23, 1995, pages 5762-5772, XP002089661 cited in the application abstract; Fig.1; page 5763, right column; page 5765 + 5766 + 5770 --- -/-</p>	1-37



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

27 July 1999

Date of mailing of the international search report

10/08/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
 Fax: (+31-70) 340-3016

Authorized officer

Holtorf, S

INTERNATIONAL SEARCH REPORT

Inte. Application No

PCT/SG 99/00012

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DING, S-W., ET AL.: "an interspecies hybrid RNA virus is significantly more virulent than either parental virus" PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE USA, vol. 93, July 1996 (1996-07), pages 7470-7474, XP002089662 cited in the application the whole document ---	1-37
A	DING, S-W., ET AL.: "efficient infection from cDNA clones of cucumber mosaic cucumovirus RNAs in a new plasmid vector" JOURNAL OF GENERAL VIROLOGY, vol. 76, 1995, pages 459-464, XP002089663 abstract ---	1-37
A	DING, S-W., ET AL.: "new overlapping gene encoded by the cucumber mosaic virus genome" VIROLOGY, vol. 198, 1994, pages 593-601, XP002089664 cited in the application abstract; page 593, 595, 596; Fig. 1,2; page 597-600 ---	1-37
A	WO 93 25068 A (CORNELL RES FOUNDATION INC) 23 December 1993 (1993-12-23) page 2; examples 11-14 ---	1-37
A	WO 96 21032 A (ASGROW SEED CO ; TRICOLI DAVID M (US); CARNEY KIM J (US); RUSSELL P) 11 July 1996 (1996-07-11) üpage 2,3,12 ---	1-37
A	WO 91 15585 A (RIJKSLANDBOUWHOGESCHOOL) 17 October 1991 (1991-10-17) abstract; pages 2,6; claims ---	1-37
T	LI, H-W., ET AL.: "strong host resistance targeted against a viral suppressor of the plant gene silencing defence mechanism" THE EMBO JOURNAL, vol. 18, no. 10, May 1999 (1999-05), pages 2683-2691, XP002110358 the whole document -----	24-37

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/SG 99/00012

Patent document cited in search report	Publication date	Patent family member(s)			Publication date
WO 9325068	A 23-12-1993	EP 0673423	A	27-09-1995	
		JP 7507457	T	24-08-1995	
		US 5633449	A	27-05-1997	
		US 5596132	A	21-01-1997	
-----	-----	-----	-----	-----	-----
WO 9621032	A 11-07-1996	AU 2690295	A	24-07-1996	
		EP 0819176	A	21-01-1998	
		TR 960640	A	21-07-1996	
-----	-----	-----	-----	-----	-----
WO 9115585	A 17-10-1991	NL 9000773	A	01-11-1991	
		AT 174931	T	15-01-1999	
		AU 642252	B	14-10-1993	
		AU 7684591	A	30-10-1991	
		CA 2056439	A	03-10-1991	
		DE 69130660	D	04-02-1999	
		DE 69130660	T	17-06-1999	
		EP 0474857	A	18-03-1992	
		EP 0874055	A	28-10-1998	
		ES 2128318	T	16-05-1999	
		JP 5505110	T	05-08-1993	
		PT 97230	A, B	31-12-1991	
		US 5866776	A	02-02-1999	
-----	-----	-----	-----	-----	-----

INTERNATIONAL SEARCH REPORT

Inte. .onal Application No

PCT/SG 99/00012

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12N15/82 C07K14/08 C12N15/62 A01H5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>DING, S-W., ET AL.: "a novel naturally occurring hybrid gene encoded by a plant RNA virus facilitates long distance virus movement" THE EMBO JOURNAL, vol. 14, no. 23, 1995, pages 5762-5772, XP002089661 cited in the application abstract; Fig.1; page 5763, right column; page 5765 + 5766 + 5770 --- -/-</p>	1-37



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

27 July 1999

Date of mailing of the international search report

10/08/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl
 Fax: (+31-70) 340-3016

Authorized officer

Holtorf, S

INTERNATIONAL SEARCH REPORT

Inte. .onal Application No

PCT/SG 99/00012

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DING, S-W., ET AL.: "an interspecies hybrid RNA virus is significantly more virulent than either parental virus" PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE USA, vol. 93, July 1996 (1996-07), pages 7470-7474, XP002089662 cited in the application the whole document ---	1-37
A	DING, S-W., ET AL.: "efficient infection from cDNA clones of cucumber mosaic cucumovirus RNAs in a new plasmid vector" JOURNAL OF GENERAL VIROLOGY, vol. 76, 1995, pages 459-464, XP002089663 abstract ---	1-37
A	DING, S-W., ET AL.: "new overlapping gene encoded by the cucumber mosaic virus genome" VIROLOGY, vol. 198, 1994, pages 593-601, XP002089664 cited in the application abstract; page 593,595,596; Fig. 1,2; page 597-600 ---	1-37
A	WO 93 25068 A (CORNELL RES FOUNDATION INC) 23 December 1993 (1993-12-23) page 2; examples 11-14 ---	1-37
A	WO 96 21032 A (ASGROW SEED CO ;TRICOLI DAVID M (US); CARNEY KIM J (US); RUSSELL P) 11 July 1996 (1996-07-11) üpage 2,3,12 ---	1-37
A	WO 91 15585 A (RIJKSLANDBOUWHOGESCHOOL) 17 October 1991 (1991-10-17) abstract; pages 2,6; claims ---	1-37
T	LI, H-W., ET AL.: "strong host resistance targeted against a viral suppressor of the plant gene silencing defence mechanism" THE EMBO JOURNAL, vol. 18, no. 10, May 1999 (1999-05), pages 2683-2691, XP002110358 the whole document -----	24-37

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/SG 99/00012

Patent document cited in search report	Publication date	Patent family member(s)			Publication date
WO 9325068	A 23-12-1993	EP 0673423	A	27-09-1995	
		JP 7507457	T	24-08-1995	
		US 5633449	A	27-05-1997	
		US 5596132	A	21-01-1997	
-----	-----	-----	-----	-----	-----
WO 9621032	A 11-07-1996	AU 2690295	A	24-07-1996	
		EP 0819176	A	21-01-1998	
		TR 960640	A	21-07-1996	
-----	-----	-----	-----	-----	-----
WO 9115585	A 17-10-1991	NL 9000773	A	01-11-1991	
		AT 174931	T	15-01-1999	
		AU 642252	B	14-10-1993	
		AU 7684591	A	30-10-1991	
		CA 2056439	A	03-10-1991	
		DE 69130660	D	04-02-1999	
		DE 69130660	T	17-06-1999	
		EP 0474857	A	18-03-1992	
		EP 0874055	A	28-10-1998	
		ES 2128318	T	16-05-1999	
		JP 5505110	T	05-08-1993	
		PT 97230	A,B	31-12-1991	
		US 5866776	A	02-02-1999	
-----	-----	-----	-----	-----	-----

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		